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THE COST OF WATER TREATMENT BY COAGULATION, SEDIMENTATION, AND RAPID SAND FILTRATION. PART 2

Louis Koenig-Research
San Antonio, Texas

November 1966

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THE COST OF WATER TREATMENT

by

COAGULATION, SEDIMENTATION

and

RAPID SAND FILTRATION

Part 2 of a Report

for

U. S. PUBLIC HEALTH SERVICE
Division of Water Supply and Pollution Control
Technical Services Branch
Under Purchase Order No. 2-1868

Now Federal Water Pollution Control Administration
Technical Services Branch

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San Antonio, Texas

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CHAPTER 1

INTRODUCTION

In March 1966 there was issued Part 1 of a report on this subject, Chapter 8 of which indicated that studies were planned on the influence of water quality parameters on cost elements and also on some relationships among the non-cost operating ratios.

That section of the work was implemented by the Federal Water Pollution Control Administration Purchase Order No. 2-1868 dated March 30, 1966. The present report constitutes the intended Part 2 containing elements of analysis and conclusions as mutually agreed upon and specifically set forth in correspondence culminating in letter of 6 October 1966 from E. L. Johnson, Chief Economist, FWPCA, to Louis Koenig-Research.

The computer portions of the project were performed under the direction of William C. Pisano, FWPCA, on a computer at the National Bureau of Standards. The IBM cards were punched from data supplied by LK-R by Data Processing Center, San Antonio. Louis Koenig was Project Director and Larry Jureski, Research Assistant, supplied the mathematical and statistical analyses.

CHAPTER 2

RESULTS OF MULTIVARIATE REGRESSION ANALYSIS

Punched Card Deck

A set of IBM punched cards was produced at San Antonio containing the data to be analyzed. There were two such decks one comprising the monthly data and the other comprising the period average data for each plant. Each month or period for each plant was represented by 3 cards conforming to the format used in the intramural program of FWPCA. These cards were sent to FWPCA for running the computer program and copies of the printout sheets were returned to San Antonio for mathematical and statistical analysis.

Computer Programs Performed

The computer program was divided into three phases, comprising types of data and into three stages comprising types of computer manipulation of these data. The three phases were:

10 Intra-plant correlations on monthly data

20 Inter-plant correlations on monthly data

30 Inter-plant correlations on multi-month averages

where the 1, 2 and 3 in the second place refers to the numbering of the printout sections.

The three stages were:

01 SLURP

02 Principal components analysis and Varimax rotation

03 SLURP on the important variables as revealed by 02

where the number in the first place corresponds to the numbering of the printout sections.

For example, printout section number 12 comprises the PCA and VM on the intra-plant correlations of monthly data. The rationale behind the three stages was as follows. The original SLURP analysis in stage 01 performed on various combinations of dependent and independent variables showed a large number of significant correlations between the variables. However, it developed that there was some intercorrelation among the five primary water quality parameters and the 02 stage was required to explore and eliminate this interdependence. In general it is found that the dependent variables correlate

primarily with turbidity and temperature and occasionally with one of the set of the remaining three, hardness, alkalinity and pH. These last three are the parameters which are intercorrelated. It happens that these three parameters would be intercorrelated if the waters in the communities were all for example calcium bicarbonate waters. Such waters would have a relatively fixed relation between hardness, alkalinity and pH. The same would be true if the waters had been adjusted to a state of calcium carbonate equilibrium and measured by the Langelier Saturation Index or by the Ryznar Stability Index. This subject was not thoroughly explored because in general the correlation with the hardness, alkalinity, pH set was relatively weak.

The third stage of the computer program took the important variables as shown by the 02 stage and proceeded with a SLURP analysis on these important variables, stepping in one at a time, starting with the most important variable as in the normal SLURP Program.

Results of Computer Program

The 02 stage of the operation in effect discarded a large number of attempted correlations which were shown to have no "important variables". In other words for these relations a correlation did not exist. A list of the regressions which were tried and thus discarded is presented in Table 1.

One might elaborate on various relations in the table but the major conclusion to be drawn is that any relation between variables which appear in this table is not a significant correlation measured by the data of this project.

The results for the final 03 stage are shown in Tables 2, 3 and 4. These tables list every regression among the variables which was performed in the 03 stage on the important variables.

TABLE 1

LIST OF REGRESSION RELATIONS ATTEMPTED WHICH WERE DISCARDED IN THE 02 STAGE AS NOT SHOWING ANY "IMPORTANT VARIABLES"

Printout Section	Plant No. & Job No. in 01 Stage	Category	Dependent Variable	Independent Variable
11	Job 3	Large Conv.	Alkali dosage	WQP
11	Job 5	Small Conv.	Rational filter run	WQP
11	Job 5	Small Conv.	% backwash	WQP
11	Job 6	Small Conv.	Rational filter run	WQP
11	Job 7	Small Conv.	Rational filter run	WQP
11	Job 7	Small Conv.	% backwash	WQP
11	Job 8	Small Conv.	Alum dosage	WQP
11	Job 8	Small Conv.	Alkali dosage	WQP
11	Job 8	Small Conv.	Rational filter run	WQP
11	Job 8	Small Conv.	% backwash	WQP
11	Job 12	Large Conv.	% backwash	WQP
11	Job 13	Large Conv.	Alum dosage	WQP
11	Job 13	Large Conv.	Rational filter run	WQP
11	Job 14	Small SSCC	Alum dosage	WQP
11	Job 19	Large Conv.	Rational filter run	WQP
11	Job 19	Large Conv.	% backwash	WQP
11	Job 21	Large Conv.	Rational filter run	WQP
11	Job 21	Large Conv.	% backwash	WQP
11	Job 22	Large SSCC	Rational filter run	WQP
11	Job 23	Small Conv.	Alum dosage	WQP
11	Job 23	Small Conv.	Alkali dosage	WQP
11	Job 23	Small Conv.	Rational filter run	WQP
11	Job 23	Small Conv.	% backwash	WQP
11	Job 29	Large Conv.	% backwash	WQP

Continued on next page

TABLE 1 (Cont'd)

Printout Section	Plant No. & Job No. in 01 Stage	Category	Dependent Variable	Independent Variable
31	20000		Design conv. sed. basin det. time	WQP
31	20001		Design SSCC det. time	WQP
31	20003		Design filter rate	WQP
31	20004		Std. Investment cost dev. ratio from regr. line	WQP
31	20006	Large	Av. chem. cost at median prices	WQP
31	20007	Small	Av. chem cost at median prices	WQP
31	20009		Rational filter run	WQP and av. conv. det. time
31	20010		Rational filter run	WQP and av. SSCC det. time
31	20011		Rational filter run	WQP and av. det. time dev ratio from median
31	20012		Rational filter run	WQP
31	20014		% backwash	WQP and av. SSCC det. time
31	20017	Large	Alum dosage	WQP
31	20018	Small	Alum dosage	WQP
31	20019	Large	Alkali dosage	WQP
31	20020	Small	Alkali dosage	WQP and alum dosage

TABLE 2

REGRESSIONS ON "IMPORTANT VARIABLES" PHASE 10 INTRA-PLANT, MONTHLY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
								Independent Variables								Dependent Variables											
Category	Plant No. and Problem No. / Equation No.	Print-out Section	Color	Av. Conv. det. time mins.	Av. SSCC det. time mins.	Av. det. time ratio t median dimensionless	Det. time min.	Alum dosage (av. or monthly) lbs/mg	Log turb. ppm	Hardness ppm $CaCO_3$	Temp. °F	pH	Alkalinity ppm $CaCO_3$	Turb. ppm	Free CO_2 ppm	Alum dosage (av. or monthly) lbs/mg	Alkali dosage (av. or mo.) lbs/mg	Rational filter run (av. or mo.) Kgal sf.bw.	% backwash (av. or mo.)	coagulant chem. aid cost $/Kgal	Design sed. Conv. SSCC or ratio	Av. chem. time cost, large or small ratio ¢/Kgal	Design filter rate gpm/sf.	Inv. cost, dev. ratio	% H_2O to clean sed. basins	Constant	F (x, y) and F number
large conv.	P-1	13							524							✓										-798	(1, 12)
	E-1								.925																		.856
large conv.	P-1	13							1519				7.23			✓										-3551	(2, 11)
	E-2								2.71				2.91														4.94
large conv.	P-1	13							3422	15.73			-5.30			✓										-7865	(3, 10)
	E-3								4.05	2.66			-1.04														7.46
large conv.	P-1	13										6.99						✓								-48.54	(1, 12)
	E-4											2.72															7.40
large conv.	P-1	13								-0.03		6.69						✓								-41.75	(2, 11)
	E-5									-1.43		3.71															5.06
large conv.	P-1	13								-.0290		6.71		-.00447				✓								-41.36	(3, 10)
	E-6									-.850		2.56		-.0623													3.07
large conv.	P-1	13								-.0290		6.71		-.00447				✓								-41.4	(3, 10)
	E-7									-.850		2.56		-.0623													3.07
large conv.	P-1	13								-.0672	.109	12.8		-.0368				✓								-87.5	(4, 9)
	E-8									-1.75	1.72	2.99		-.540													3.48
large conv.	P-1	13					-.00108			-.0409	.0480	10.8		.0193				✓								-74.5	(5, 8)
	E-9						-1.38			-.992	.638	2.50		.251													3.44
large conv.	P-2	13										-343				✓										2730	(1, 19)
	E-1											-3.27															10.7
large conv.	P-2	13									-2.60	-225				✓										1970	(2, 18)
	E-2										-1.85	-1.91															7.74
large conv.	P-2	13								-1.77	-1.89	-256				✓										2380	(3, 17)
	E-3									-2.33	-1.46	-2.41															8.23
large conv.	P-2	13						.989									✓									198	(1, 19)
	E-4							7.08																			50.2
large conv.	P-2	13						.715				-260					✓									2230	(2, 18)
	E-5							4.98				-3.17															42.1

Continued on next page

TABLE 2 (cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
large conv.	P-2	13						.677			-.627	-245					✓									2160	(3, 17)
	E-6							4.24			-.605	-2.80															27.2
large conv.	P-2	13							-1.74		.0332							✓								6.01	(2, 18)
	E-8								-3.42		3.83																42.1
large conv.	P-2	13							-1.74		.0333		-.0000686					✓								6.02	(3, 17)
	E-9								-2.60		3.17		-.0072														8.94
large conv.	P-2	13							-1.25	.00969	.0310							✓								3.83	(3, 17)
	E-10								-1.94	1.25	3.56																10.3
large conv.	P-2	13								-.0223										✓						6.04	(1, 19)
	E-11									-3.86																	14.9
large conv.	P-2	13								-.0198	-.0184									✓						6.88	(2, 18)
	E-12									-3.77	-2.46																12.5
large conv.	P-2	13								-.0176	-.0189			.000629						✓						6.49	(3, 17)
	E-13									-2.76	-2.47			.615													8.14
large conv.	P-3	13											.684													-2.78	(1, 19)
	E-1												5.80														33.6
large conv.	P-3	13									.107		.512						✓							-6.59	(2, 18)
	E-2										2.33		3.95														23.4
large conv.	P-3	13									-.167									✓						4.64	(1, 19)
	E-3										-3.99																15.9
large conv.	P-3	13									-.0256		-.125							✓						5.56	(2, 18)
	E-4										-1.46		-2.53														9.48
large conv.	P-4	13							50.6								✓									43.6	(1, 23)
	E-1								5.22																		27.2
large conv.	P-4	13							44.1			-34.1					✓									285	(2, 22)
	E-2								4.20			-1.43															15.3
large conv.	P-4	13											1.43					✓								75.3	(1, 23)
	E-3												4.21														17.7
large conv.	P-4	13											1.32		8.10			✓								37.9	(2, 22)
	E-4												5.66		5.19												32.4
large conv.	P-4	13								.889			.956					✓								56.4	(2, 22)
	E-5									2.15			2.49														12.6
large conv.	P-4	13								.166			1.24		7.69			✓								36.2	(3, 21)
	E-6									.469			4.19		4.24												20.9

Continued on next page

TABLE 2 (cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
large conv.	P-4	13												-.00149					✓							1.20	(1, 23)
	E-7													-2.38													5.66
large conv.	P-4	13									-.00535			-.00137					✓							1.52	(2, 22)
	E-8										-1.66			-2.26													4.42
large conv.	P-4	13					.000682				-.00225			-.00191					✓							1.07	(3, 21)
	E-9						1.19				-.547			-2.54													3.48
small conv.	P-7	13												.717		✓										368	(1, 23)
	E-1													3.51													12.3
small conv.	P-7	13								-1.02				.519		✓										544	(2, 22)
	E-2									-2.03				2.42													9.08
small conv.	P-7	13								-2.20			1.30	.568		✓										542	(3, 21)
	E-3									-1.26			.707	2.49													6.08
small conv.	P-7	13						.303				-103					✓									763	(2, 22)
	E-5							2.76				-4.47															37.8
small conv.	P-7	13						.284				-95.2	-.235				✓									743	(3, 21)
	E-6							2.49				-3.71	-.744														24.9
small conv.	P-7	13						.277		-.276		-94.3					✓									750	(3, 21)
	E-7							2.42		-.892		-3.73															25.2
small conv.	P-7	13						.226				-98.4		.190			✓									743	(3, 21)
	E-8							1.92				-4.35		1.54													27.6
small conv.	P-10	13										236				✓										-1090	(1, 13)
	E-1											2.15															4.61
small conv.	P-10	13		4.29								143				✓										-596	(2, 12)
	E-2			.923								.961															2.70
small conv.	P-10	13						1.05									✓									-155	(1, 13)
	E-3							11.0																			122
small conv.	P-10	13		3.41				.928									✓									-209	(2, 12)
	E-4			2.58				10.1																			90.7
small conv.	P-10	13						1.06			.893						✓									-199	(2, 12)
	E-5							13.3			2.60																91.4
large conv.	P-12	13									7.27					✓										-73.1	(1, 30)
	E-1										6.86																47.0
large conv.	P-12	13		5.55							5.34					✓										-146	(2, 29)
	E-2			3.90							5.31																42.3

Continued on next page

TABLE 2 (cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
large conv.	P-12	13									5.94	134				✓										-976	(2, 29)
	E-3										3.32	.922															23.8
large conv.	P-12	13									5.47		2.86			✓										-99.4	(2, 29)
	E-4										3.35		1.44														25.4
large conv.	P-12	13												.496			✓									-6.71	(1, 30)
	E-5													6.20													38.5
large conv.	P-12	13						.0214						.465			✓									-12.7	(2, 29)
	E-6							2.03						5.98													23.3
large conv.	P-12	13		.253				.00901						.424			✓									-15.0	(3, 28)
	E-7			1.22				.615						5.05													16.3
large conv.	P-12	13						.0340									✓									3.38	(1, 30)
	E-8							2.23																			4.99
large conv.	P-12	13						.0214						.465			✓									-12.7	(2, 29)
	E-9							2.03						5.98													23.3
large conv.	P-12	13		.253				.00901						.424			✓									-15.0	(3, 28)
	E-10			1.22				.615						5.05													16.3
large conv.	P-12	13					.00599											✓								2.81	(1, 30)
	E-11						-21.6																				466
large conv.	P-12	13					-.00578					.0587						✓								2.33	(2, 29)
	E-12						-20.4					2.08															261
large conv.	P-12	13		.0000955			-.00600											✓								2.81	(2, 29)
	E-13			.190			-20.8																				226
small conv.	P-5	13											-15.7			✓										415	(1, 21)
	E-1												-2.70														7.27
small conv.	P-5	13						.953									✓									28.8	(1, 21)
	E-2							12.7																			160
small conv.	P-5	13						.923					-1.87				✓									62.0	(2, 20)
	E-3							10.4					-.681														78.4
small conv.	P-6	13											-1.02			✓										648	(1, 14)
	E-1												-1.82														3.31
small conv.	P-6	13						.384									✓									58.1	(1, 14)
	E-2							4.14																			17.2
small conv.	P-6	13						.426				9.75					✓									38.4	(2, 13)
	E-3							5.85				3.23															19.6

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TABLE 2 (cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
large conv.	P-13	13						.245									✓									17.1	(1, 29)
	E-1							5.00																			25.0
large conv.	P-13	13						.241				-39.4					✓									326	(2, 28)
	E-2							5.00				-1.47															14.1
large conv.	P-13	13									.0247								✓							.927	(1, 29)
	E-3										5.78																33.4
small SSCC	P-14	13												.0702			✓									.0302	(1, 29)
	E-1													4.81													23.1
small SSCC	P-14	13										5.18						✓								-29.8	(1, 29)
	E-2											2.13															4.53
small SSCC	P-14	13										-.713							✓							6.86	(1, 29)
	E-3											-2.23															4.97
small SSCC	P-14	13	% backwash is shown as both dep. and ind. variable on printout sheets																								
	E-4																										
small SSCC	P-14	13										-.814		.0708					✓							6.87	(2, 28)
	E-5											-2.68		2.22													5.29
large SSCC	P-15	13													11.8	✓										93.8	(1, 29)
	E-1														5.05												25.5
large SSCC	P-15	13											.966		9.74	✓										-.577	(2, 28)
	E-2												1.98		3.94												16.0
large SSCC	P-15	13											.00236								✓					-.0842	(1, 29)
	E-3												3.59														12.9
large SSCC	P-15	13										.0218	.00221								✓					-.245	(2, 28)
	E-4											1.01	3.29														6.96
large SSCC	P-15	13											-.182		-.0866			✓								24.0	(2, 28)
	E-6												-5.84		-.549												22.7
large SSCC	P-15	13									.0171									✓						2.92	(1, 29)
	E-7										1.39																1.93
large SSCC	P-15	13									.0136		.0591							✓						-3.00	(2, 28)
	E-8										1.11		1.58														2.26
large conv.	P-17	13												5.80		✓										-42.0	(1, 25)
	E-1													16.5													272
large conv.	P-17	13									-.108			5.70		✓										-35.4	(2, 24)
	E-2										-1.28			15.9													140
large conv.	P-17	13									.00530			-.0530				✓								6.92	(2, 24)
	E-4										1.22			-2.87													6.02

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TABLE 2 (cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
large conv.	P-17	13											.413						✓							-2.10	(1, 25)
	E-5												3.33														11.1
large conv.	P-17	13								.00969		.359							✓							-2.53	(2, 24)
	E-6									1.41		2.81															6.75
small SSCC	P-18	13												6.00		✓										-17.5	(1, 29)
	E-1													4.82													23.2
small SSCC	P-18	13									.0697			.0492					✓							9.10	(2, 28)
	E-8										-4.04			2.25													16.2
large conv.	P-19	13												2.81		✓										38.5	(1, 25)
	E-1													3.35													11.2
large conv.	P-19	13									-.304			2.44		✓										58.3	(2, 24)
	E-2										-.955			2.64													6.06
large conv.	P-21	13									.947					✓										11.2	(1, 29)
	E-1										4.35																18.9
large conv.	P-21	13									.943	44.8				✓										-344	(2, 28)
	E-2										4.70	2.48															14.2
large conv.	P-21	13									.891		-.210			✓										42.7	(2, 28)
	E-3										3.83		-.718														9.57
large conv.	P-21	13									.736	72.0	-.766			✓										-444	(3, 27)
	E-4										3.75	3.76	-2.71														14.1
large SSCC	P-22	13								-1.43						✓										496	(1, 21)
	E-1									-2.59																	6.71
large SSCC	P-22	13								-2.20	-3.01					✓										815	(2, 20)
	E-2									-4.12	-3.01																9.18
large SSCC	P-22	13						.00659											✓							2.32	(1, 21)
	E-3							4.14																			17.1
large SSCC	P-22	13						.00500		-.0349									✓							9.27	(2, 20)
	E-4							3.36		-2.84																	15.5
large conv.	P-29	13								-7.43						✓										822	(1, 31)
	E-1									-10.4																	109
large conv.	P-29	13								-9.76			2.14			✓										868	(2, 30)
	E-2									-7.67			2.16														63.1
large conv.	P-29	13								-9.53			3.02	1.18		✓										746	(3, 29)
	E-3									-7.61			2.69	1.56													44.9

Continued on next page

TABLE 2 (cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
large conv.	P-29	13						.441									✓									196	(1, 31)
	E-4							4.38																			19.2
large conv.	P-29	13						.444		.0305							✓									193	(2, 30)
	E-5							2.04		.0166																	9.28
large conv.	P-29	13						.461			1.76						✓									69.3	(2, 30)
	E-6							5.35			3.53																19.4
large conv.	P-29	13						.568		1.02	1.81						✓									41.2	(3, 29)
	E-7							3.03		.645	3.56																12.8

TABLE 3

REGRESSIONS ON "IMPORTANT VARIABLES" PHASE 20 INTER-PLANT, MONTHLY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
									Independent Variables							Dependent Variables											
Category	Plant No. and Problem No. / Equation No.	Print-out Section	Plant Numbers Involved				Det. time, min.	Alum dosage (av. or mo.) lbs/mg	Log turb. ppm	Hard-ness ppm $CaCO_3$	Temp. °F	pH	Alka-linity ppm $CaCO_3$	Turb. ppm	Free CO_2 ppm	Alum dosage (av. or mo.) lbs/mg	Alkali dosage (av. or mo.) lbs/mg	Rational filter run (av. or mo.)	% back-wash (av. or mo.)	coagu-lant chem. aid cost $/Kgal	Design sed. conv. SSCC or ratio mins.	Av. chem. large or small ratio ¢/Kgal	De-sign filter rate gpm/sf.	Inv. cost, dev. ratio	% H_2O to clean sed. basins	Con-stant	F(x, y) and F number
large	P-11110	23	1, 2, 3, 4, 13, 15,									-8.99	-.874			✓										286	(2, 258)
	E-2		17, 19, 21, 29									-.538	-5.29														41.7
large	P-11110	23	"							.225		-11.2	-1.00			✓									●	293	(3, 257)
	E-3									1.48		-.669	-5.37														28.6
large	P-11110	23	"										-1.00	-.176		✓										237	(2, 258)
	E-4												-9.59	-2.68													46.2
small	P-11120	23	7, 14, 26, 28											2.77		✓										91.2	(1, 61)
	E-1													7.56													57.2
small	P-11120	23	"									-82.3		2.56		✓										724	(2, 60)
	E-2											-2.23		6.96													32.9
small	P-11120	23	"								5.62	-44.9		2.34		✓										136	(3, 59)
	E-3										3.95	-1.30		7.03													32.5
small	P-11120	23	"									-82.3		2.56		✓										724	(2, 60)
	E-4											-2.22		6.96													32.9
large	P-11130	23	2, 3, 4, 13, 29											.274			✓									174	(1, 129)
	E-1													2.87													8.21
large	P-11130	23	"						-64.8					.565			✓									251	(2, 128)
	E-2								-2.08					3.35													6.38
large	P-11130	23	"						-72.3		1.79			.598			✓									149	(3, 127)
	E-3								-2.37		2.72			3.62													6.94
small	P-11130	23	7, 26, 28							-.147		-90.9					✓									821	(2, 29)
	E-3									-.491		-3.67															41.4
small	P-11130	23	"									-86.1	-.240				✓									794	(2, 29)
	E-4											-3.82	-.800														42.2
small	P-11130	23	"							-1.11	.171						✓									266	(2, 29)
	E-5									-6.35	.204																23.7
small	P-11130	23	"								.329		-1.21				✓									253	(2, 29)
	E-6										.395		-6.31														23.4

Continued on next page

TABLE 3 (cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
small	P-11180	23		7, 26, 28						-.134	-.523	-95.8					✓									887	(3, 28)
	E-7									-.444	-.723	-3.70															27.3
small	P-11180	23		"							-.495	-91.0	-.222				✓									859	(3, 28)
	E-8										-.687	-3.81	-.729														27.3
small	P-11180	23		"					41.0	-1.12							✓									208	(2, 29)
	E-9								2.09	-7.34																	29.4
small	P-11180	23		"					40.6				-1.23				✓									206	(2, 29)
	E-10								2.05				-7.24														28.7
small	P-11180	23		"					30.0	-.228		-82.9					✓									721	(3, 28)
	E-11								1.75	-.782		-3.40															30.6
small	P-11180	23		"					30.3			-79.4	-.311				✓									701	(3, 28)
	E-12								1.79			-3.60	-1.07														31.4
conv.	P-11160	23		1, 2, 3, 7, 17, 19, 21							.0595			-.00982				✓								3.66	(2, 163)
	E-2										4.38			-4.49													18.2
conv.	P-11160	23		"							.0543		-.0111	-.0110				✓								5.38	(3, 162)
	E-3										4.02		-2.57	-5.01													14.8
conv.	P-11160	23		"						.0187	.0348	-.0885	-.0256	-.0139				✓								7.02	(5, 160)
	E-4									3.18	2.40	-.120	-3.47	-5.99													11.4
SSCC	P-11170	23		14, 15, 26, 28			-.0303						-.0351					✓								17.3	(2, 66)
	E-2						-7.26						-1.74														27.9
conv.	P-11190	23		2, 3, 4, 7, 17,										.00435					✓							1.55	(1, 208)
	E-1			19, 21, 29										6.27													39.3
conv.	P-11190	23		"								.710		.00493					✓							-3.87	(2, 207)
	E-2											6.43		7.69													44.1
conv.	P-11190	23		"						.00207		.596		.00474					✓							-3.19	(3, 206)
	E-3									1.57		4.54		7.28													30.4
conv.	P-11190	23		"						.00813	-.00971	1.07	-.0103	.00368					✓							-5.72	(5, 204)
	E-4									4.60	-2.56	6.18	-4.69	5.59													24.9
SSCC	P-11200	23		14, 15, 26, 28			.0187											✓								-1.24	(1, 67)
	E-1						10.9																				119
SSCC	P-11200	23		"			.0219						.0348					✓								-5.24	(2, 66)
	E-2						12.8						4.21														83.5
SSCC	P-11200	23		"			.0219					.285	.0276					✓								-6.78	(3, 65)
	E-3						12.7					.429	1.49														55.0

TABLE 4

REGRESSIONS ON "IMPORTANT VARIABLES" PHASE 03 INTER-PLANT, PERIOD AVERAGES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
								Independent Variables								Dependent Variables											
Category	Plant No. and Problem No. Equation No.	Print-out Section	Plant Numbers Involved				Det. time, min.	Alum dosage (av. or mo.) lbs/mg	Log turb. ppm	Hard-ness ppm $CaCO_3$	Temp. °F	pH	Alka-linity ppm $CaCO_3$	Turb. ppm	Free CO_2 ppm	Alum dosage (av. or mo.) lbs/mg	Alkali dosage (av. or mo.) lbs/mg	Rational Filter run (av. or mo.) $\frac{Kgal}{sf.bw}$	% back-wash (av. or mo.)	coagu-lant chem. aid cost $/Kgal	Design sed.time SSCO ratio mins.	Av. chem. cost, large or small ratio ¢/Kgal	De-sign filter rate gpm/sf	Inv. cost, dev. ratio	% H_2O to clean sed. basins	Con-stant	F (x, y) and F number
	P-40,000	33											-.00325												✓	.586	(1, 10)
	E-1												-2.73														7.45
	P-40,000	33								-.000380			-.00293												✓	.593	(2, 9)
	E-2									-.182			-1.35														3.38
	P-40,000	33								-.000130		.387	-.00577												✓	-2.09	(3, 8)
	E-3									-.0626		1.10	-1.72														2.71
	P-40,001	33									.0404											✓				-1.35	(1, 17)
	E-1										2.59																6.69
	P-40,001	33									.0391			.00189								✓				-1.39	(2, 16)
	E-2										2.79			2.29													6.82
	P-40,002	33												.00238					✓							1.81	(1, 10)
	E-1													2.70													7.29
	P-40,002	33								.00371				.00221					✓							1.48	(2, 9)
	E-2									1.37				2.58													4.89
	P-40,002	33								.00310		.114		.00221					✓							.676	(3, 8)
	E-3									.799		.230		2.45													2.94
	P-40,002	33									.128								✓							-5.08	(1, 15)
	E-1										2.78																7.71
	P-40,002	33									.163	1.40							✓							-17.7	(2, 14)
	E-2										3.41	1.73															5.86
	P-40,003	33									.0493										✓					-1.90	(1, 17)
	E-1										3.96																15.7
	P-40,004	33									.0379	-.445									✓					2.13	(2, 16)
	E-2										3.07	-2.23															12.2
	P-40,004	33				1.76													✓							.227	(1, 15)
	E-1					6.81																					46.4
	P-40,004	33				1.60					.0290								✓							-1.33	(2, 14)
	E-2					5.08					.843																23.1

To illustrate the meaning of the tables attention is directed to the first entry in Table 2. Column 1 indicates that this is Job 1 on the printout sheets for Plant #1, a large plant having conventional sedimentation basins. Column 2 is the plant number as identified in the main report. Column 3 is the printout section in which the correlation is found, namely 13 (read one three). The 1 signifies that this is a correlation of intra-plant monthly data. The 3 indicates that this is the result of the final SLURP operation on the important variables, i.e. stage 03. In Column 10 under independent variables, the entry in the top line, 524, is the coefficient of log turbidity (ppm) in the regression equation. The check mark in Column 17 under dependent variables, alum dosage, indicates that alum dosage is a dependent variable. The -798 in Column 27 is the constant in the equation, which therefore is:

alum dosage, lbs/mg = 524 log turbidity, ppm -798

The top entry in Column 28 (1, 12) comprises the directions for finding the F statistic in the F tables. The 1 is the number of independent variables. The 12 is the number of points minus the number of independent variables -1. The bottom row in Column 10 and the bottom row in Column 28 is the t or F value. That in Column 28, 0.856, is the F value for the correlation by means of which the significance is judged. The bottom row in Column 10, 0.925, is the Student's t value by which is determined the significance of the particular variable with which it is associated. In this first entry in the table neither the F number or the t number are underlined and this indicates that neither were significant at the 1% level. One concludes for this entry that the correlation of monthly alum dosage with monthly turbidity for Plant Number 1 is not significant at the 1% level.

One may question why the 1% level of significance was chosen rather than the more customary 5% level. The reason is as follows. As will be indicated later the computer program produced a large number of correlations having unusually high F numbers. This would ordinarily be interpreted that there were a large number of correlations among the data and that these correlations were of a high degree of significance. However as will be seen a great many of these correlations which were highly significant statistically proved to be highly suspicious physically. One way to weed out some of these spurious physical correlations is to increase the stringency of the significance level.

A second reason for choosing the 1% level may stem from ignorance on the part of LK-R as to the statistical sophistication of the SLURP Program. If a 5% level of significance means that in 1 case out of 20 the F test would indicate that there is a correlation when the universe of data actually shows no correlation, then consider what happens when one selects the best correlation from among the 5 or more variables that are involved in most regression relations in this study. If there is 1 chance in 20 that the F test will show a correlation when there really is no correlation with a single variable, then when the program is allowed to select the best correlation from among 5 independent variables it would appear that the chance for a false indication of correlation is now 1 in 4 rather than 1 in 20. Possibly the SLURP Program actually takes this into account in some way in generating the F number. But if it does not this may be one explanation for the large number of highly significant correlations which are physically untenable.

As a second example attention is directed to the third entry in Table 2 which is the same data into which have stepped three variables: turbidity, hardness and alkalinity. The regression equation is:

$$\text{alum dosage} = 3422 \log \text{turbidity} + 1573 \text{ hardness} - 5.30 \text{ alkalinity} - 7865$$

This equation had three independent variables and 10 degrees of freedom. One may deduce that 14 points were involved in the correlation. The F in Column 28 is underlined which signifies that it is significant at the 1% level. Likewise the t number in Column 10 is underlined indicating that the coefficient of the log turbidity term is significant and thus it is the most important variable, the other two being of less importance such that their coefficients are not significant by the t test.

The same scheme is used in the 23 and 33 sections of the table except that there Columns 4, 5, 6 and 7 are used to designate the numbers of the plants supplying data to the correlation.

Nature of Physical Inconsistency

When the final correlations are examined in detail there are found to be many inconsistencies among the correlations, both inconsistencies from the physical standpoint and also inconsistencies between plants. Some of these examined by means of Table 5.

TABLE 5

EXAMPLES OF TYPES OF INCONSISTENCIES

Section 13	Coefficient On:								Category	Problem # Equation #
	Free CO_2	Turb.	Alkali	pH	Hard. ness	Log turb.	Alum	Det. time	Temp.		
Alum vs						+3422				Large conv.	P-1, E-1
				-343						Large conv.	P-2, E-1
						+50.6				Large conv.	P-4, E-1
		+.717								Small conv.	P-7, E-1
									+5.34	Large conv.	P-12, E-2
	+11.8									Large SSCC	P-15, E-1
		+5.80								Large conv.	P-17, E-1
		+6.00								Small SSCC	P-18, E-1
		+2.81								Large conv.	P-19, E-1
				+72.0						Large conv.	P-21, E-4
					-2.20				-3.01	Large SSCC	P-22, E-2
					-7.43					Large conv.	P-29, E-1
% Backwash vs					-.0198					Large conv.	P-2, E-12
									-.167	Large conv.	P-3, E-3
									+.0247	Large conv.	P-13, E-3
				+.413						Large conv.	P-17, E-5
									-.0839	Small SSCC	P-18, E-3
								+.00500		Large SSCC	P-22, E-4
Alkali vs				-260			+.715			Large conv.	P-2, E-5
	+8.10		+1.32							Large conv.	P-4, E-4
				-144						Small conv.	P-7, E-4
							+1.05			Small conv.	P-10, E-3
		+.496								Large conv.	P-12, E-5
							+.953			Small conv.	P-5, E-2
				+9.75			+.426			Small conv.	P-6, E-3
							+.245			Large conv.	P-13, E-1
		+.0702								Small SSCC	P-14, E-1
							+.441			Large conv.	P-29, E-4
							+.461		+1.76	Large conv.	P-29, E-6

Continued on next page

TABLE 5 (cont'd)

Section 23	Coefficient on: Free CO_2	Turb.	Alkali	pH	Hardness	Log turb.	Alum	Det. time	Temp.	Category	Problem # Equation #
Alum vs WQP		-.176	-1.00							Large Plants	P-11110, E-4
		+2.34							+5.62	Small Plants	P-11120, E-3
Alkali vs WQP and Alum		+.598							+1.79	Large Plants	P-11130, E-3
			-1.24							Small Plants	P-11140, E-2

The correlations shown for alum dosage versus water quality parameters indicate the important variables found in this correlation for each plant for which any important variable was found. The numbers in the body of the table are the coefficients of that term in the regression equation, for example for Plant #1, on the first row, the regression equation is:

alum dosage = 3422 log turbidity + a constant (unspecified)

A glance through the coefficients in this section of the table shows very little consistency among the various plants as to what the alum dosage may be correlated with. Some depend upon turbidity or log turbidity, some upon pH, some upon hardness, temperature, and even free CO_2. There are six that depend upon turbidity or log turbidity and there is a consistency in the sign of the coefficient in the sense that the alum dosage increases as the turbidity increases. However if there were a real correlation, in a common sense meaningful for predictions, between alum and turbidity one would expect to find turbidity appearing as the important variable in a majority of the plants. Actually it so appears in only 6 plants out of about 25 in which it had the opportunity to so appear. Other inconsistencies are that one plant showed an increase of alum dosage with pH and the other showed a decrease. One plant showed a decrease of alum dosage with increasing temperature but the other two showed an increase with increasing temperatures which is physically unlikely.

In percent backwash, temperature is the most important variable for the largest group of plants, 3 out of about 25. But in two of these plants the coefficient is negative, in the other positive. Physically one might expect that percent backwash depends upon the turbidity of the effluent from the sedimentation device, which in turn presumably ought to be influenced by turbidity, detention time, alum dosage, and possibly temperature.

The alkali dosage appears to show some consistency in that 7 plants, out of about 25 candidates, show a correlation with alum dosage in the sense that the alkali dosage increases with the alum dosage. This undoubtedly represents the stoichiometric relationship that alkali is necessary to hold the pH against the acidic alum. However alum dosage is not a water quality parameter, and until either the alkali dosage or the alum dosage can be predicted independently from water quality parameters this relation cannot be utilized.

The correlations of alkali dosage with the other water quality parameters show the same types of inconsistencies present in the other examples.

In Section 23 which is the correlation for the inter-plant monthly data the alum dosage for the small plants depends upon alkalinity and turbidity and for the large plants upon temperature and turbidity. However in the large plants the alum dosage decreases with turbidity while in the small plants it increases with turbidity.

The alkali dosage shows the important variables of turbidity and temperature for the large plants and of alkalinity for the small plants. In neither case is there any significant dependence of alkali dosage upon alum dosage, which is quite the contrary to the situation previously described for alkali dosage in the intra-plant correlation.

To summarize, in the whole body of data it has not been possible to find a single relationship which is both statistically significant, free from internal or external inconsistencies with other data, and not physically untenable. There is no result of this program upon which we would wish to base a prediction as to the performance of a non-interviewed plant as a function of its water quality parameters.

SUPPLEMENTARY COMMENTS ON CORRELATIONS

There follow some comments on miscellaneous correlations which may or may not appear in the Tables resulting from analyses performed manually subsequent to the computer work.

Percent Basin Cleaning Water vs Alkalinity — This correlation is not significant at 1% but it was at 5%. A plot of all plants providing data points on alkalinity and percent basin cleaning water showed six points which arose from plants which did not have a complete block of data and therefore were not included in the computer correlation. When these six points are placed on the graph along with the points involved in the correlation, it is obvious that there is no correlation at all between these two quantities.

Percent Back-wash vs Temperature — This correlation was not significant at 1% but it was a 5%. A plot of the data shows that such correlation as exists comes about solely through a single point for Plant #26. When this single point out of the 17 points is omitted it is obvious that there is no correlation.

Design Detention Time-Deviation Ratio from Median vs Temperature

The correlation of the data is significant but the relation indicates that higher temperature calls for higher detention times on the part of the designer. It is very unlikely that any attention is paid by the designer to water temperature in selecting detention times, but if this should be the case it certainly is not in the direction of reducing the detention time for colder water.

Effect of Lime Dosage on Chemical Cost

The results indicate that there is a significant multivariate correlation for the deviation from the regression line for chemical costs at median prices vs temperature and turbidity. The individual correlations are not significant at the 1% level but they are at the 5% level. Further exploration of this indicates that the major determinant of deviation ratio chemical cost at median prices is whether or not lime is used in the treatment. The chemical cost is higher if lime is used than if lime is not used. However, it has not been possible to make any determination from water quality parameters as to whether or not lime is to be used. If the analyses were run on the data divided into two sets, those with lime and those without lime, it is certain that there would be no correlation with temperature. There might remain a correlation with turbidity for one or the other or both of these sets but this subject has not been resolved and is suggested for further study.

Deviation Ratios for Alum Dosage and Alkali Dosage

Since a study has been made on deviation ratio of chemical cost at median prices for the purpose of allowing a combination of the large plants with the small plants, it is suggested for future work that a similar study on deviation ratio for the main components of chemical costs, namely alum dosage and alkali dosage be similarly performed.

Investment Versus Detention Time

It appeared possible that the requirements of the various regulatory agencies might introduce differences in investment among plants under their various jurisdictions. For example, Texas requires a six hour detention time while some other states require only a four hour, and some allow even less. This is about the only item with any appreciable bearing on investment cost which appears in the requirements. The sedimentation basin is one of the definable subcost elements, as described in Part 1 of the report but does not constitute a major percentage of the total investment. To explore the effect of detention time on investment a plot was made of detention time versus deviation ratio for unit investment, both for conventional sedimentation basins and for suspended solids contact clarifiers. The plot clearly indicated that there was no trend of deviation ratio with design detention time for either category. From this it may be inferred that while the requirements of state agencies may determine the sizes of sedimentation basins for particular plants, the other unidentifiable dispersions in investment are much greater than any discernable trend of investment with design detention time, and thus with regulatory agency requirements.

CHAPTER 3

"IF WE WERE STARTING AGAIN"

If we were starting again with the same appropriation and the same objective there are very few changes which would be made in the project. It is our belief that there has been extracted from the communities surveyed all the information that can possibly be used in a study of costs or the relation of water quality parameters to costs. This is not strictly true for some of the plants that had excellent detailed daily records going back for 30 years. Such a plant might be studied in much greater detail to determine the relationships for that plant. However, since there was so little similarity of correlation from plant to plant such a study would be a fine exercise and informative for the manager of that particular plant but would not be of much use to the managers of other plants or for predicting the performance of other plants.

We definitely would not bother with the introductory letter since project experience was that the letter was entirely unnecessary. We would however be careful to inform each State Health Department of the proposed project and interview itinerary.

Possibly we might wish to rearrange the 30-plant sample to contain a few more suspended solids contact clarifiers, but this statement is subject to modification or reversal pending an analysis of just how much more information (on the conventional versus clarifier comparison) might be obtained by such a switch.

An outside observer of this project might hope that the experience on the project might allow a better prediction as to which communities would have good records and which should be avoided because they do not have such. Actual project experience however shows that it is completely impossible to make such a prediction. There is no adequate way to find out how good a plant's records are on technical and cost matters except to actually go and interview the plant.

As a result of analysis of the 30-plant sample it can definitely be recommended that the restrictions on sub-classes of equipment and processing be considerably relaxed. To what extent that relaxation should go is not explored here but many of the excluded

sub-classes such as types of mixing basins, types of baffling in sedimentation basins and even the use of iron salts rather than alum as a coagulant should be relaxed in any future project. These things are known from the present sample to have very little influence on costs or to be of such nature that they affect only the costs directly associated with them and not any of the other cost elements.

CHAPTER 4

ADDITIONAL RESULTS FROM FURTHER ANALYSIS OF DATA

It is an LK-R specialty born of necessity on commercial projects to squeeze every last bit of information and conclusions from the available data. This practice has been applied in the present project and we defy anyone to obtain any more information out of the present data, other than the few items already suggested in connection with the multi-variate analyses. For certain purposes of our own we did produce another operating ratio: backwash water expressed in gallons/backwash/sq ft. This has a median of about 100, but it is really a direct combination of two other operating ratios, and is just a more convenient concept for certain uses.

CHAPTER 5

FURTHER EXPLORATION OF QUALITY - COST RELATIONSHIPS

In the LK-R files there is a partially completed document comprising a rough draft of a proposed chapter in the main report which was later abandoned. This partially complete Chapter explores the rational and practical relationships between water quality and the various cost elements entering into the total costs of water treatment.

For example, it discusses the effect that water quality might have on energy use through a possible requirement for higher backwash percentages etc. The exploration of this particular subject was abandoned when it became apparent that the study was not going to be able to produce costs in terms of produced water, but only in terms of raw water.

Another section of the chapter explores the relation between the specifications laid down by the various state agencies and the investment costs. For example some states, Texas being one of them, require a six hour detention time, while others allow four or sometimes even less. At one point in the study it was actually intended to plug in state requirements as a parameter to be explored for its effect on investment costs. The experimental implementation of this was abandoned when it was realized that it would require a relatively large number of plants in each state, or rather in each jurisdiction (e.g. the 10-state code). There was no indication of this effect judged by eye on the unit investment vs Q_d relation for this sample. (See page 23 of this report.)

Another approach comprised inquiries (on a very cursory basis) amongst consulting engineers who design water treatment plants to determine to what extent they took water quality parameters into account in the design of plants. Such inquiries as were made were entirely negative. We could not find any consulting engineers who admitted to tailoring their plants to the particular water qualities involved. We also approached manufacturers of some suspended solids contact clarifiers. These people took a little more cognizance of the water quality parameters but the cost differences resulting therefrom were very small. If one is really interested in tracking down any possibility of an effect of water quality parameter on treatment costs these approaches could be implemented in more thorough ways and possibly would yield some results.

The revelation that the cost of chemicals at any given $\bar{Q}$ depends much more upon whether or not alkali is included among them than upon any water quality parameter, together with the confession of an inability to determine just what makes a plant use alkali obviously calls for a further exploration of this subject. The cost differential is considerable. The matter was not subjected to statistical analysis but observation of the plots suggests that plants not using lime average about the 30 percentile of the distribution while those using lime average about the 70 percentile in chemical costs at median prices. This project was so much concerned with engineering and economics as to allow very little exploration of basic chemical relationships. It is possible that there is some not too complex relationship involving the basic water quality parameters which determines whether a plant shall use alkali or not. This is undoubtedly worth exploration. However, it should be pointed out that one of the parameters is admitted by the entire profession to be purely empirical. The universally recommended jar test is an admission that no one is good enough a chemist to tell a plant how much alkali or at what pH, or how much alum is best for the coagulation reaction.

Considerable additional work is suggested by the several attempts expressed in the report, properly qualified as heoric, in trying to draw whatever shred of conclusion could be found in the available data. Some of these involve the economics of mechanical sludge removal in conventional sedimentation basins, the economics of clarifiers versus conventional sedimentation basins, and the relative contributions of the various portions of the physical plant such as the basins, the filters, the buildings, etc. The last of these definitely cannot be explored from existing data available at the plants or with the consulting engineers. Neither plants, nor municipalities, nor contractors, nor consulting engineers break down their costs in the way cost engineering researchers would like to have them. It is suggested that this is an area for out-and-out cost estimation by a competent cost estimator who is willing to break down the estimate into the various physical components of the plant. It is unlikely that the Department could persuade a consulting engineer engaged on an actual plant to so break down his cost estimates. Therefore it is suggested that such can only be accomplished by a research type contract which would involve cost estimation in the desired form for treatment plants that will never be built.

Possibly there may be some vague hope that the Construction Grants operation of the Department, if it is applied to water treatment plants, might set up a requirement for cost estimates in this form. On second thought, possibly this hope could be more than vague. If as the LK-R report suggests the cost of the building is some 40% of the cost of the plant possibly it can be considered the responsibility of a granting agency to see if this is true, and if so whether it cannot be reduced without affecting the performance.

Another general subject which could be explored with additional data is the differential between large and small plants. One expects to find that the unit manpower for small plants is greater than for large plants. However one is surprised to find that the unit chemical consumption and unit pumping energy is quite uniformly greater in small plants than in large. No theoretical rationale for this can be found. Any chemist would confidently expect that the amount of chemicals required to coagulate a gallon of water does not change depending upon whether that gallon finds itself going through the plant along with 1000 other gallons or with 10 million other gallons.

In the preceding an attempt has been made to mention some of the items of additional data or additional exploration of the data that might shed further light on the quality-cost relationship. In addition however, there are some larger extensions of this project, which it will be recalled was set up as a pilot project, that should be mentioned.

Obviously the study calls out for extension by covering the entire spectrum of plant sizes rather than the two relatively narrow size bands that the available funds restricted us to. 50% of the plants are smaller than the small band, and 50% of the water is produced in plants larger than the large plants so that in either direction there is uncovered territory. The cost-capability curve shown is virtually log-log linear. This has been found to be an adequate representation of cost capability relations in general when the capability spred is not great. However over wide ranges of capability, covered in other LK-R studies on other types of plants, this relation almost universally becomes non-linear (i.e. non log-log linear). The unit costs at both the low end and the high end of the scale tend to be higher than the log-log linear relation predicted from the middle ranges.

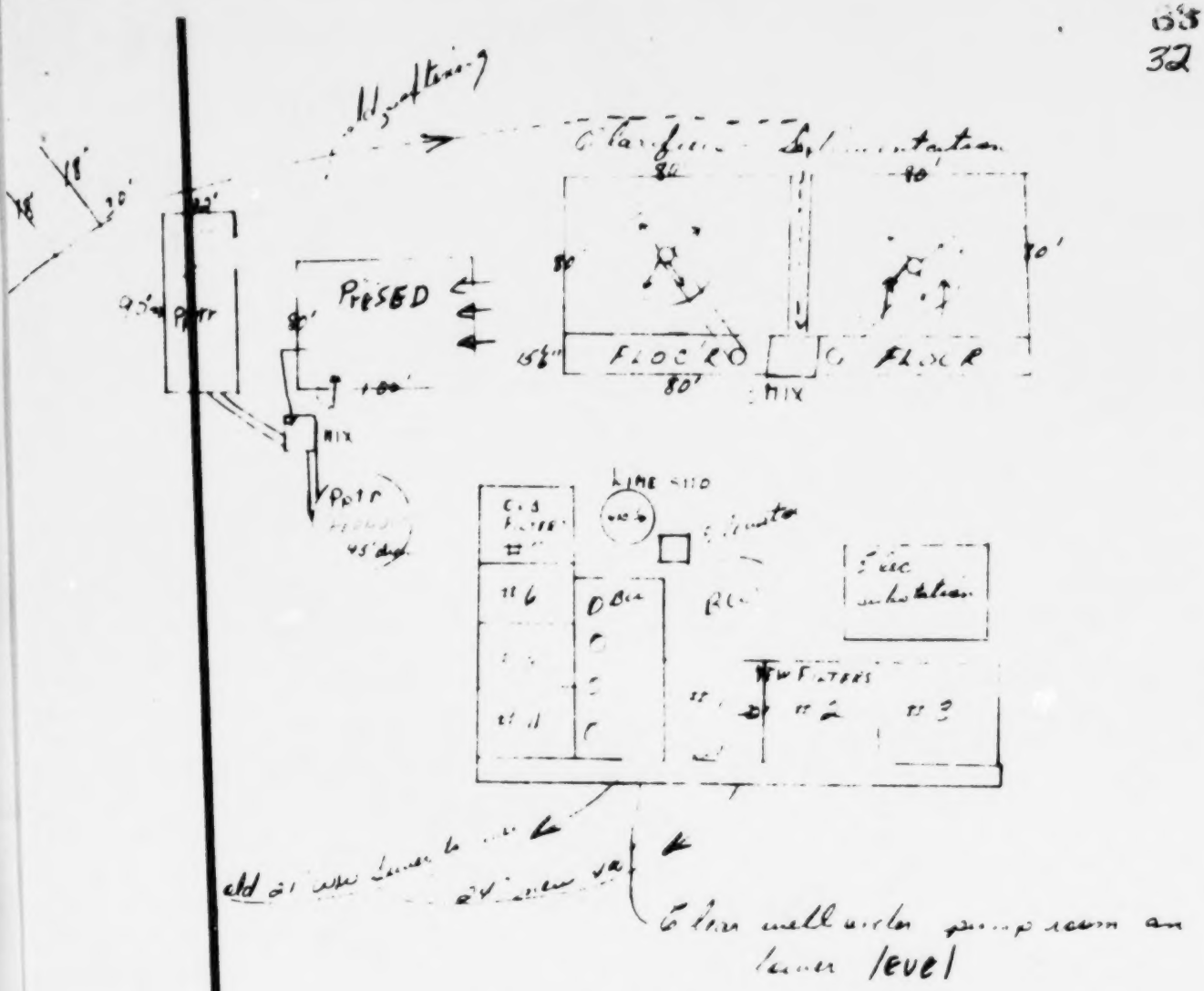
It is believed that the geographical dispersion of the sample plants cannot be well improved upon, but possibly the dispersion in water quality types can be widened, i.e. strengthened. One should look at the various possible categories of water types, bicarbonate waters, sulfate waters, alkali waters, etc., and then select the plants using these types of waters to see if such major variations in water quality parameters, or rather combinations of water quality parameters, might have more of an effect on costs than the random selection of the present project shows.

Finally, in the broadest extension of such cost studies it would appear desirable that the study be extended to the other types of treatment plants such as simple chlorination, lime-soda softening, ion exchange softening, iron and manganese removal, pressure and diatomite filtration. Probably the mission of the Department requires that it have reasonably accurate information on the costs of these various water treatment processes similar to the information it now has as a result of this study. However, in addition, speaking directly to the question of the cost-quality relationship, some exploration might be performed on the water quality parameters and the values thereof which determine for example whether a community shall have a filter plant or get by with simple chlorination. Obviously some aspects of this subject cannot be resolved by a statistical exploration of current practice. For example a city does not switch from simple chlorination to a filter plant on the basis of the cost of filtration versus the value of the damages due to enteric diseases in the community. It switches to filtration when the coliform reaches the limiting value prescribed by the State Health Department. This then becomes an aspect of the study on the relation of regulatory standards to treatment costs mentioned earlier in this discussion. However, in such treatment processes as iron and manganese removal and softening a statistical analysis of current practice together with the corresponding costs for the two treatment methods would provide the necessary information to show how treatment costs would vary in a region if water quality were changed.

CHAPTER 6

SCHEMATIC DIAGRAMS OF PLANTS

There follow schematic diagrams of the plant layout for most of the interviewed plants. These prints were made from pencil sketches, not to scale, re-drawn from the original field sketches. The field sketches were made for particular purposes in sizing equipment, and indicating flow patterns. Accordingly the diagrams do not have internal consistency in terminology, style, or detail.

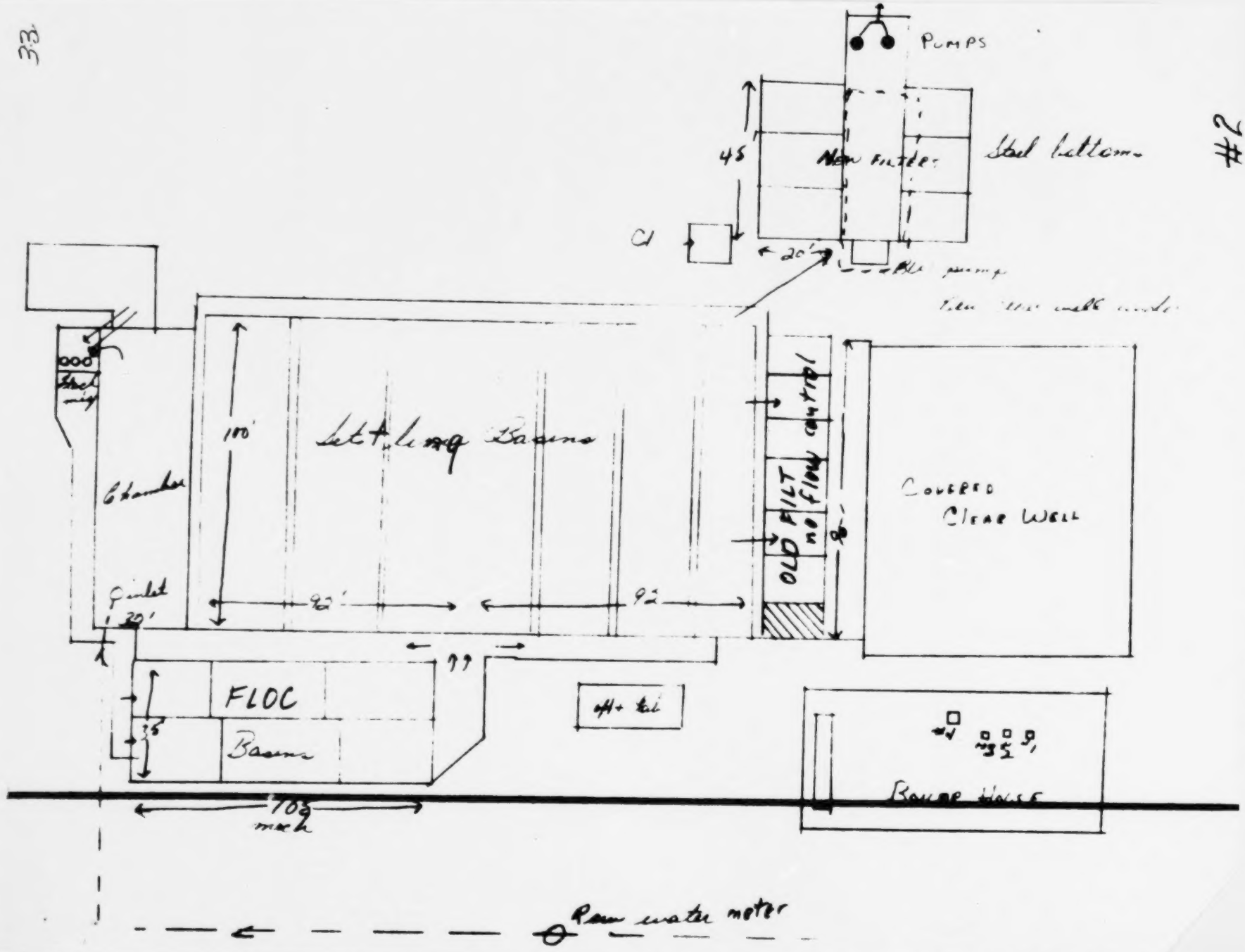


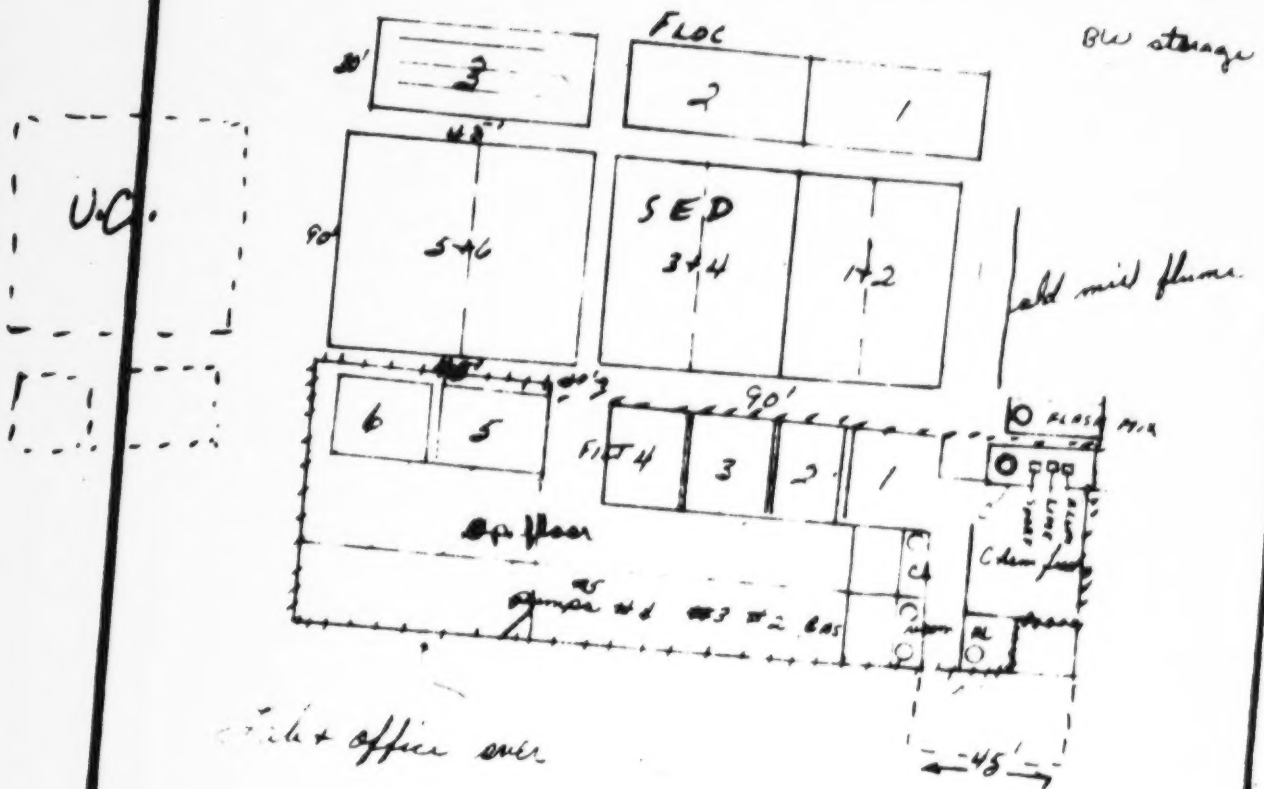
Flow in 36" to Radial

Add to central 54" pipe

Then radial to Weir in 4 cells

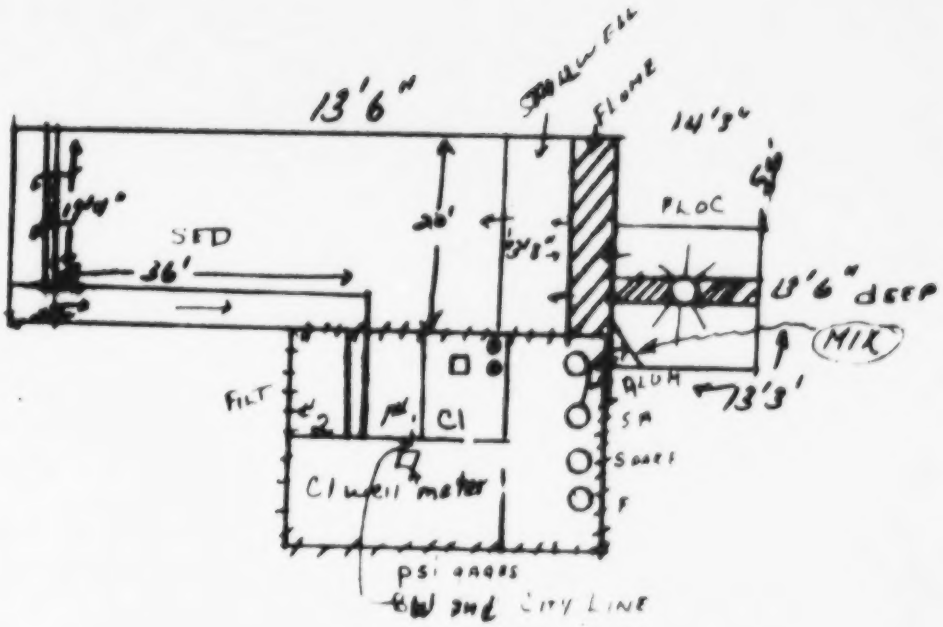
#1

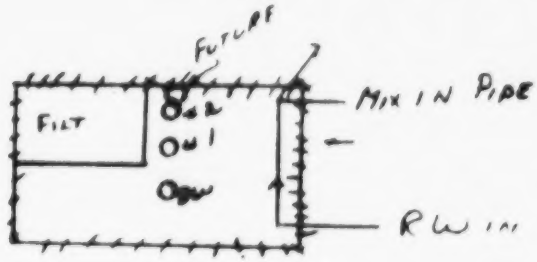

PUMPS
45
New filter
Steel bottom
Cl
20'
Chamber
100'
Settling Basins
OLD FILT
no flow control
COVERED
CLEAR WELL
Inlet
20'
90'
92'
99
FLOC
Basins
35
Backwash
Raw water meter



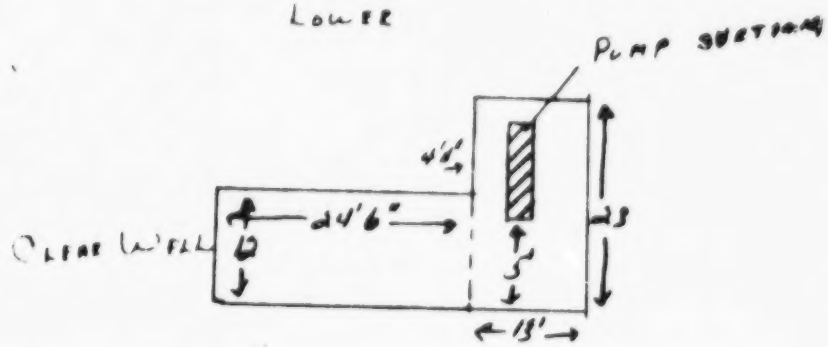
///// = housed part

#4

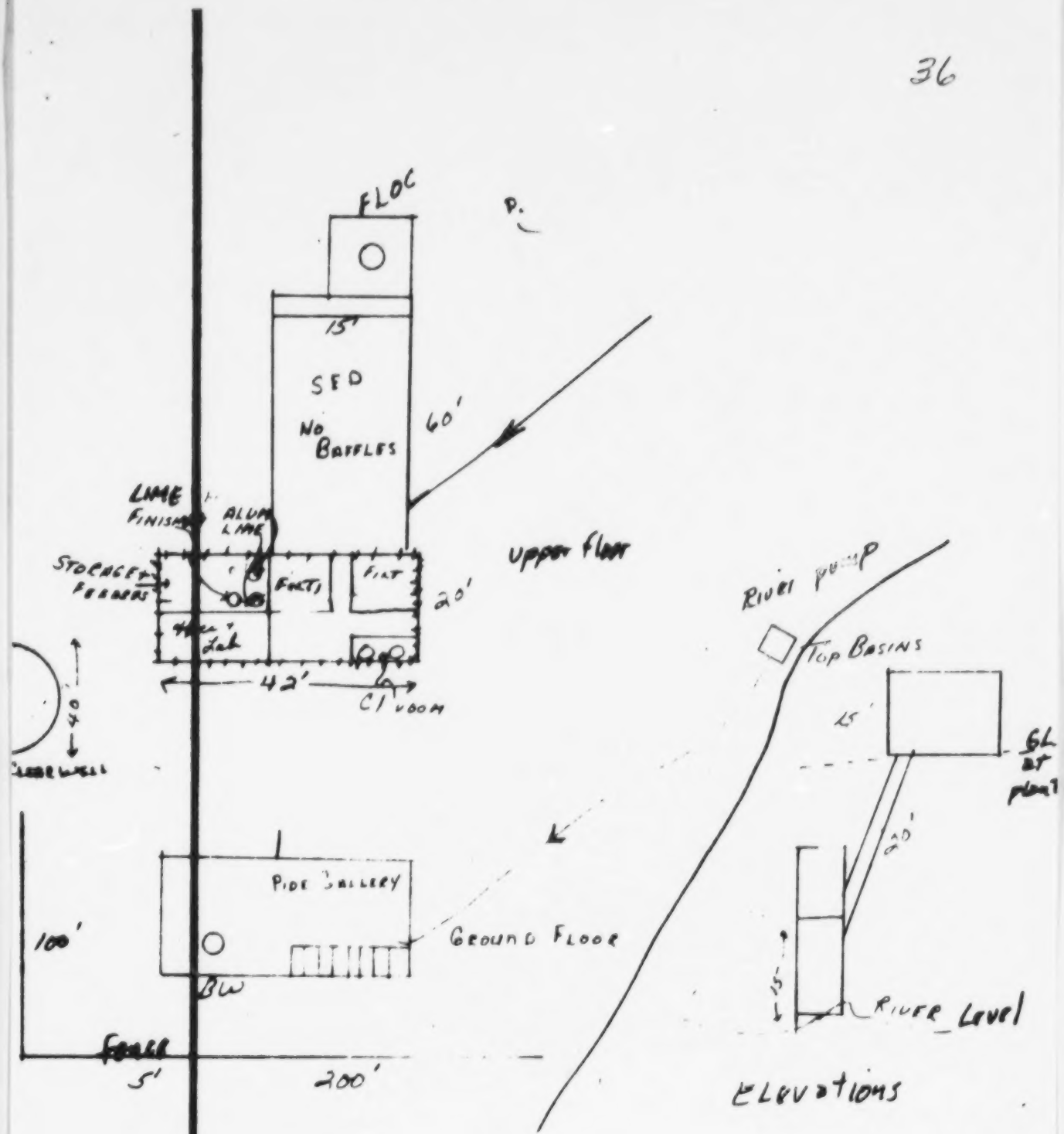

13'6"
FLOME
14'3"
PLOC
SED
36'
20'
13'6" deep
MIX
FILT
Cl
Cl well meter
SA
SOURCE
F
PSI GAGES
CITY LINE


FUTURE
MIX IN PIPE
FILT
OW1
OW2
OW3
RW IN

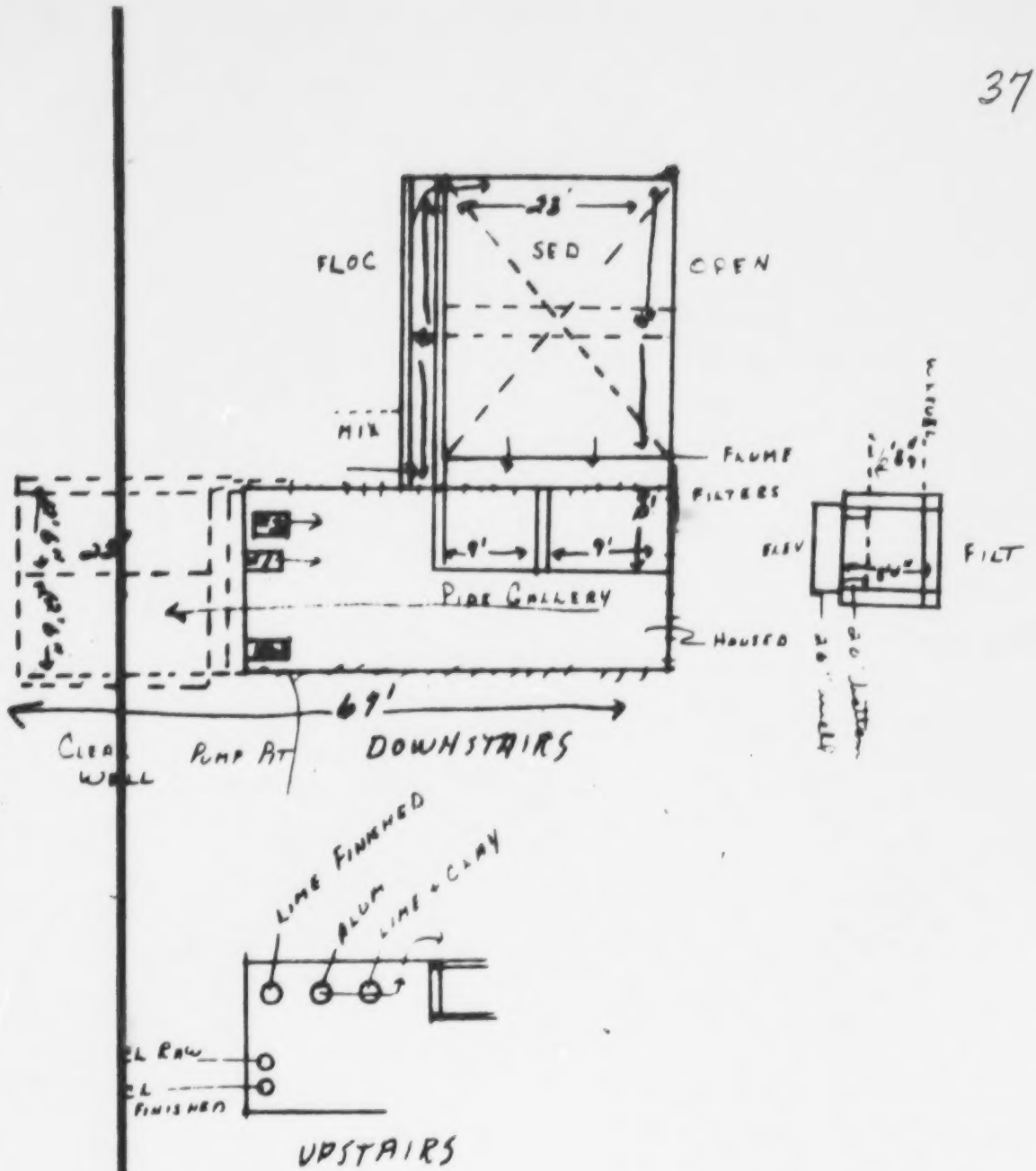
LOWER


PUMP SUCTIONS
4'6"
24'6"
CLEAR WELL
13'
13'

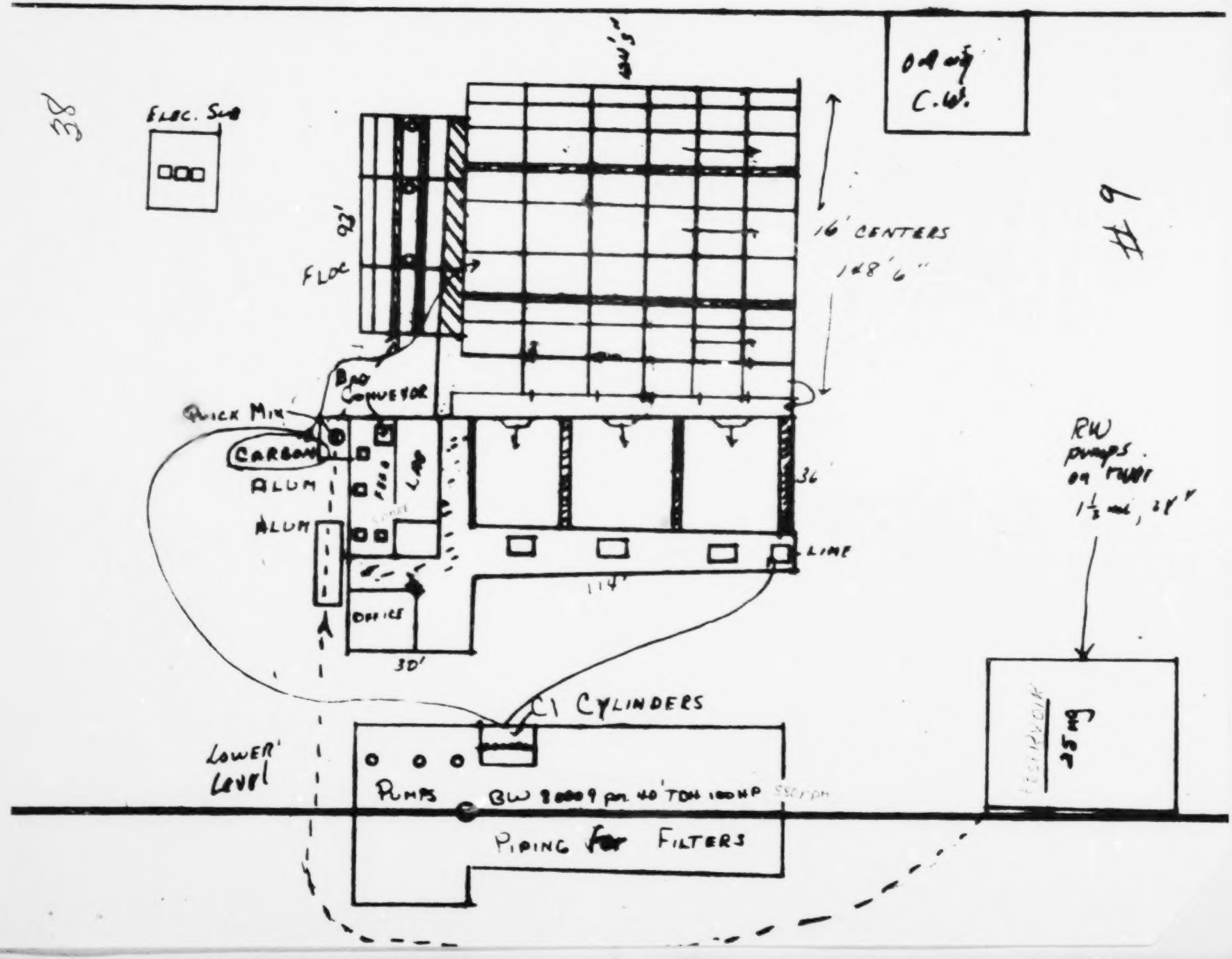
#5

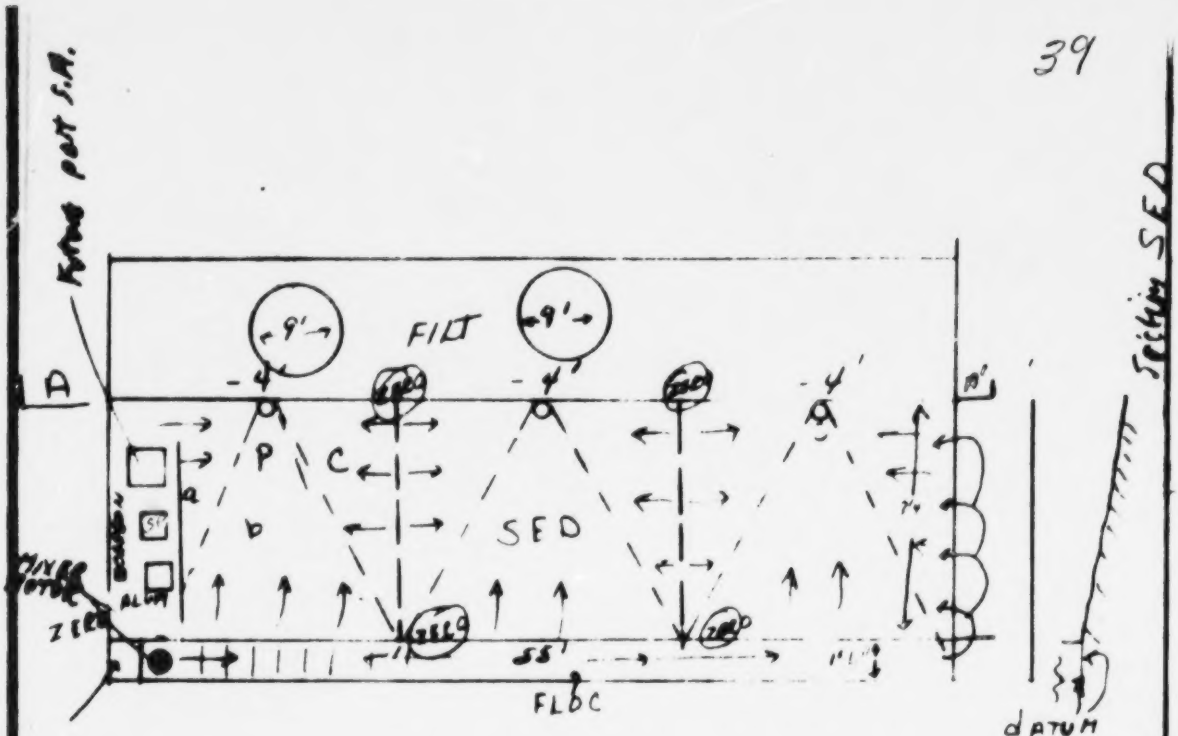

FLOC
15'
SED
NO BAFFLES
60'
LIME FINISH
ALUM LIME
STORAGE HOPPERS
FILT
FILT
20'
42'
CL ROOM
40'
CLEARWELL
PIPE GALLERY
GROUND FLOOR
100'
BW
FENCE
5'
200'
upper floor
RIVER PUMP
TOP BASINS
45'
GL AT PLANT
20'
15'
RIVER LEVEL
ELEVATIONS

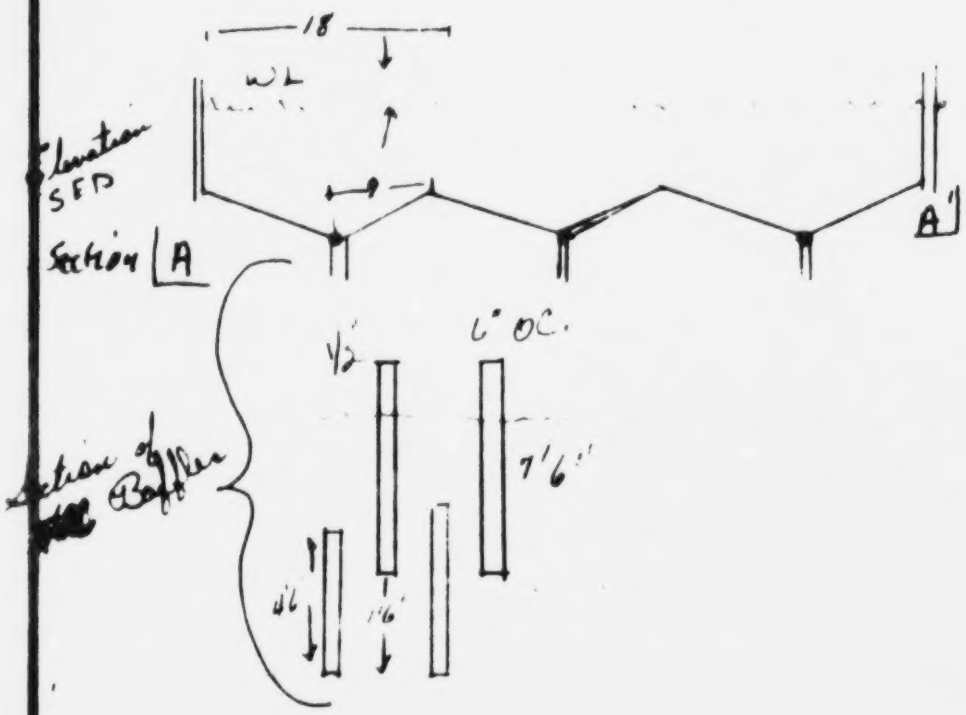
#6

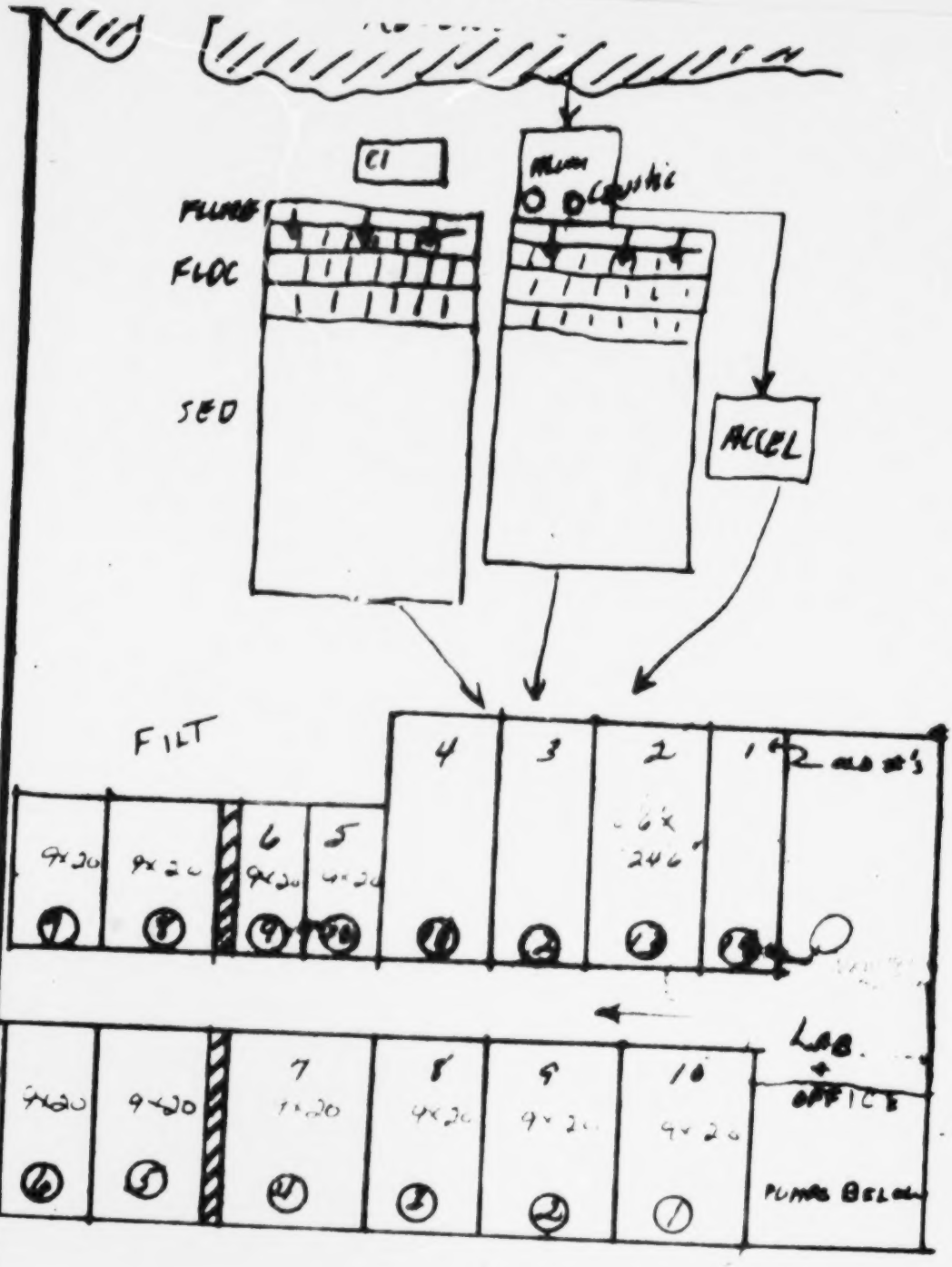

FLOC
SED
OPEN
MIX
FLUME
FILTERS
PIPE GALLERY
HOUSED
69'
DOWNSTAIRS
PUMP RM
LIME FINISHED
ALUM
LIME + CLAY
UPSTAIRS

#8

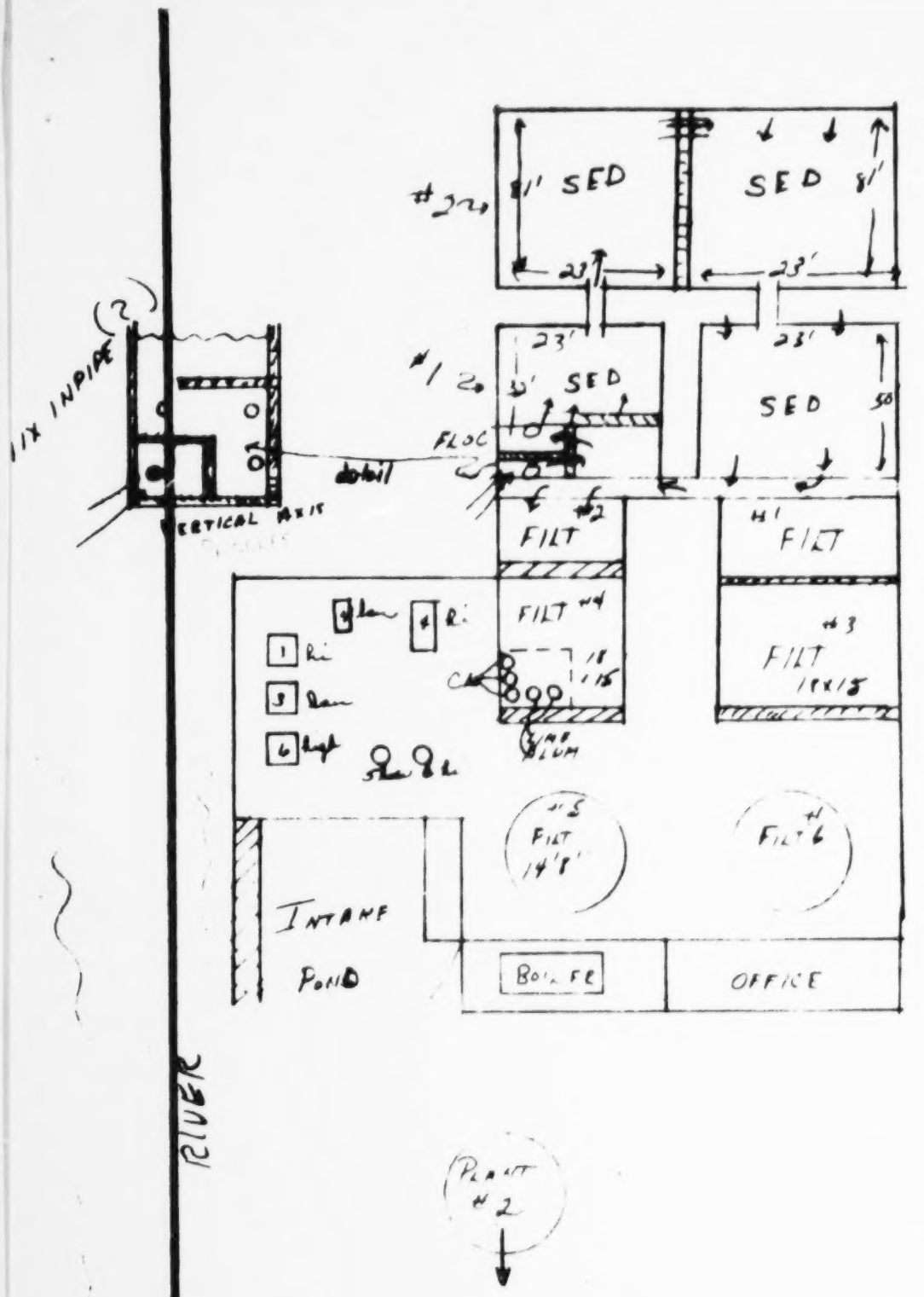

38
ELEC. SUB
23'
FLOC
16' CENTERS
148'6"
#9
BAR CONVEYOR
QUICK MIX
CARBON
ALUM
ALUM
LIME
36'
114'
OFFICE
30'
CL CYLINDERS
LOWER LEVEL
PUMPS
PIPING FOR FILTERS


FILT
9'
9'
A
P
C
SED
FLOC
DATUM
Section SED


18
WL
Elevation SED
Section A
A'
1/2
6" OC.
7'6"
Section of Baffles



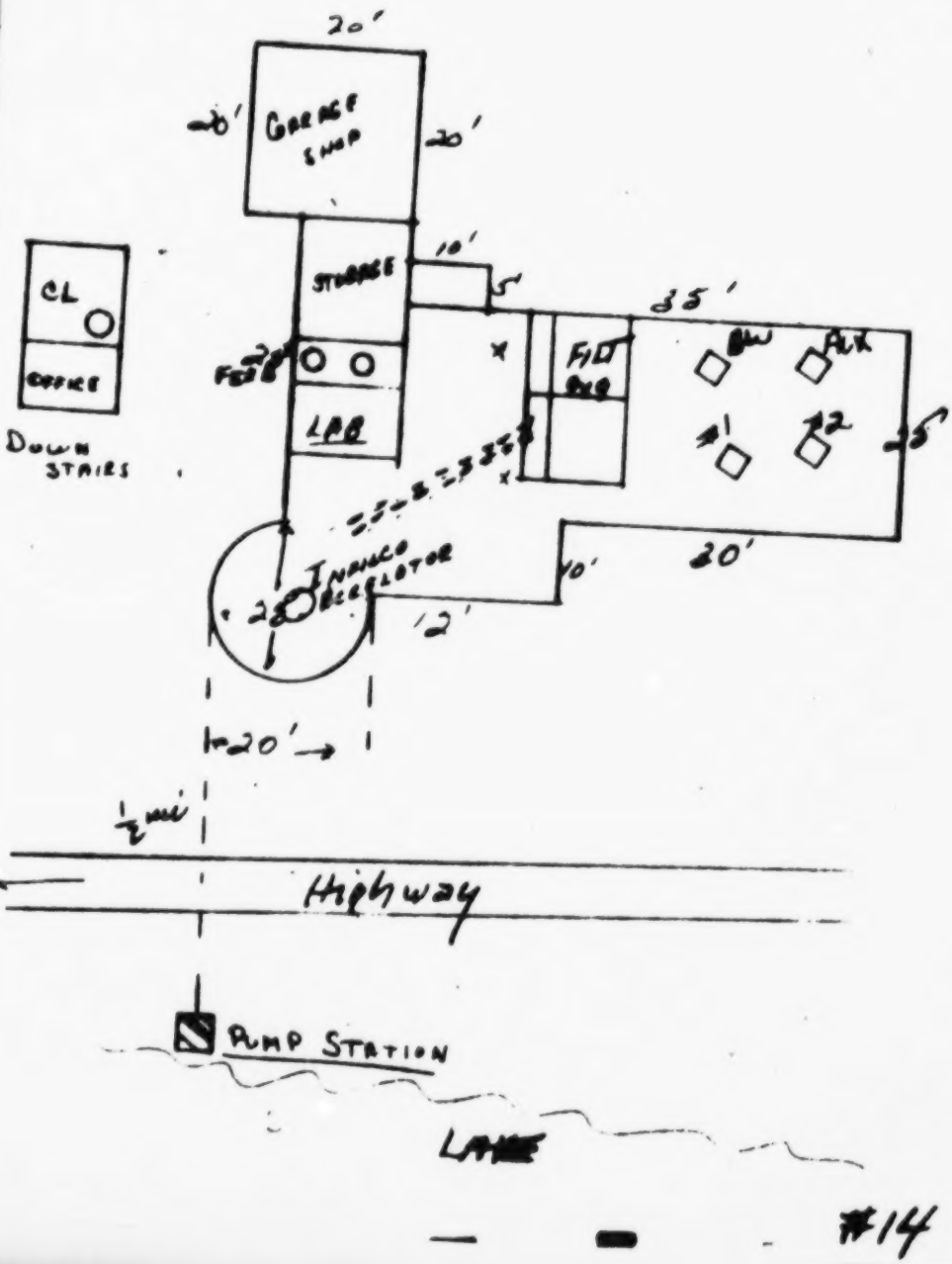
CW under whole FILT BLDG


#3
81' SED
SED 81'
23'
23'
#1 & 2
23'
23'
SED
SED
50
FLOC
FILT
#2
#1
FILT
FILT #4
#3
FILT
1 Ri
3 Ram
6
4 Ri
INTAKE
POND
#5
FILT
14'8"
#6
FILT
BOILER
OFFICE
RIVER
PLANT #2

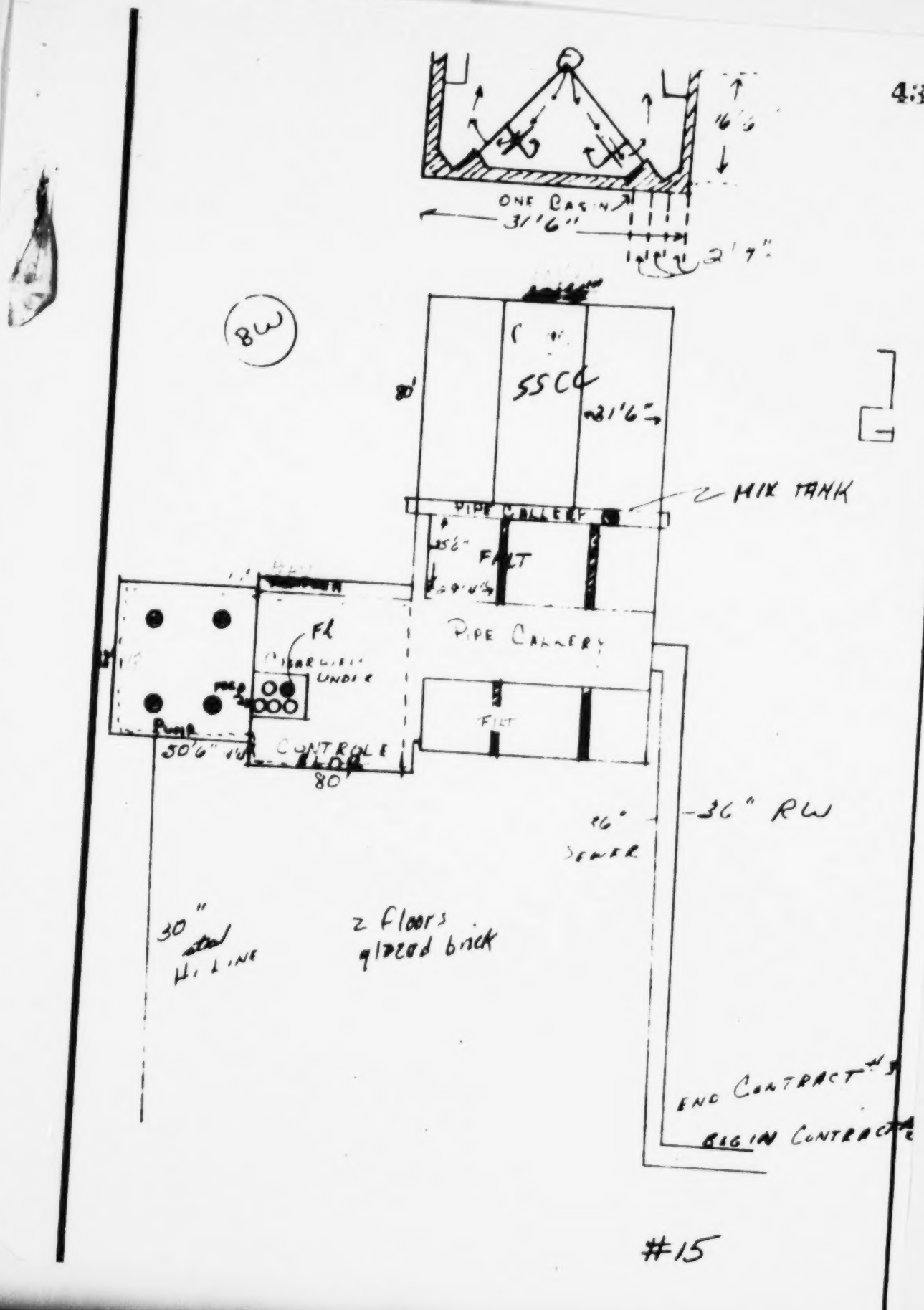
#13

All Houses

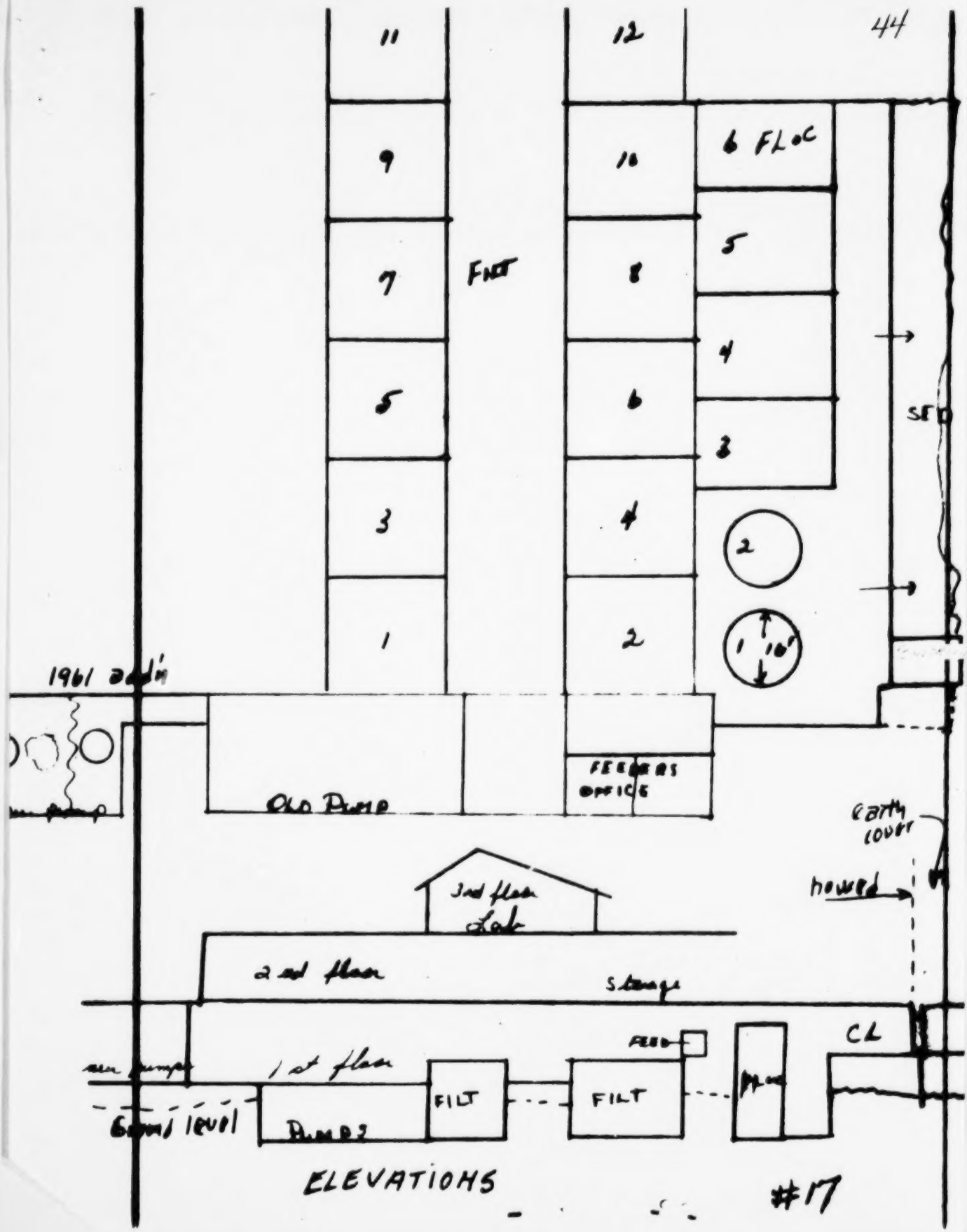
2 stories



#14

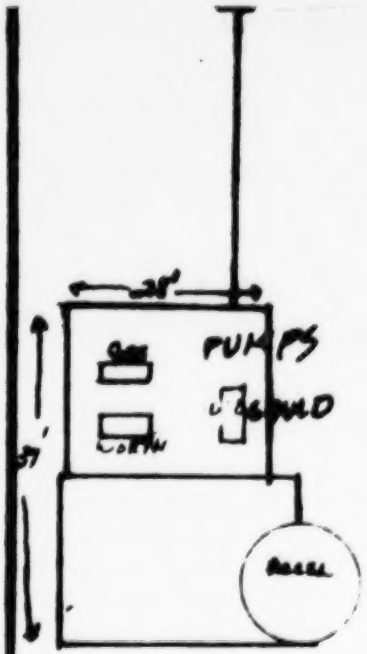

ONE BASIN
3'1'6"
2'7"
(BW)
55CC
80'
31'6"
2 MIX TANK
PIPE GALLERY
FALT
FL
PIPE GALLERY
UNDER
FILT
Pump
CONTROLE
80
36" RW
SEWER
30" steel
H. LINE
2 floors
glazed brick
END CONTRACT
BEGIN CONTRACT

#15

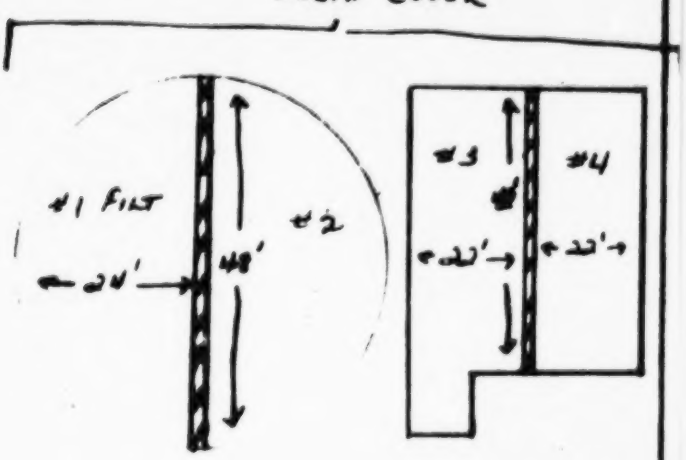


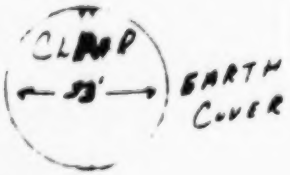
ELEVATIONS

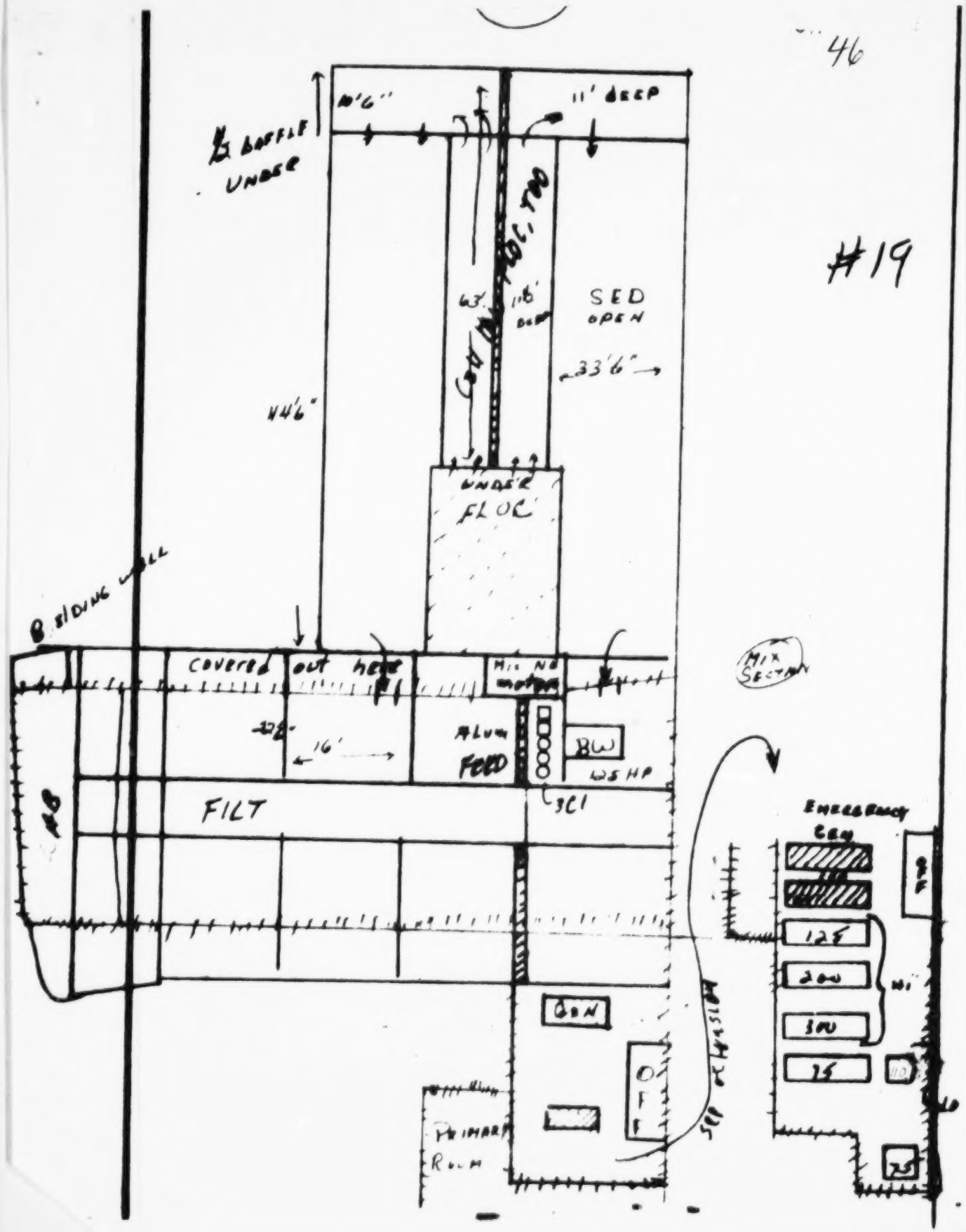
#17

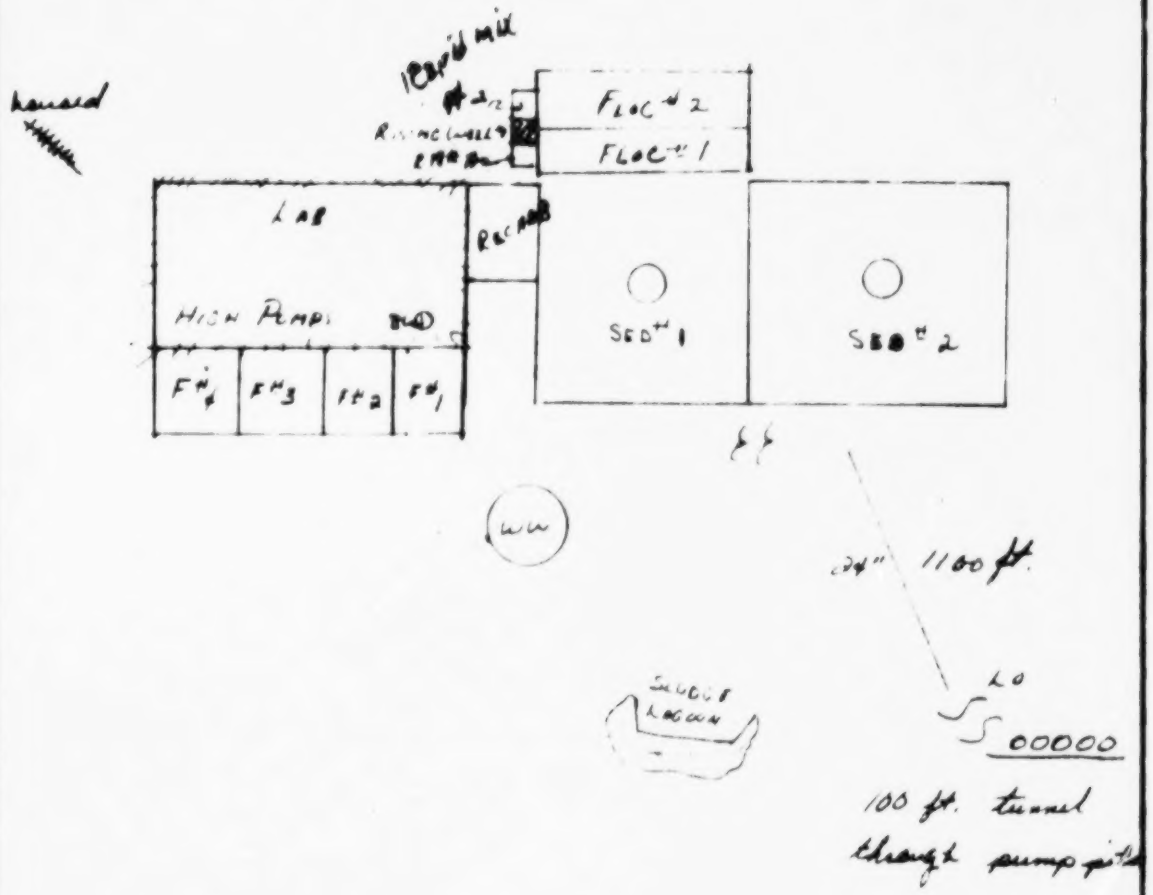


SLOW SAND FILTERS

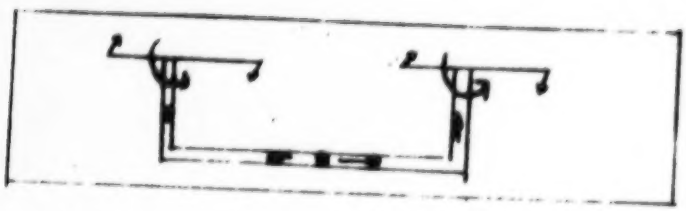




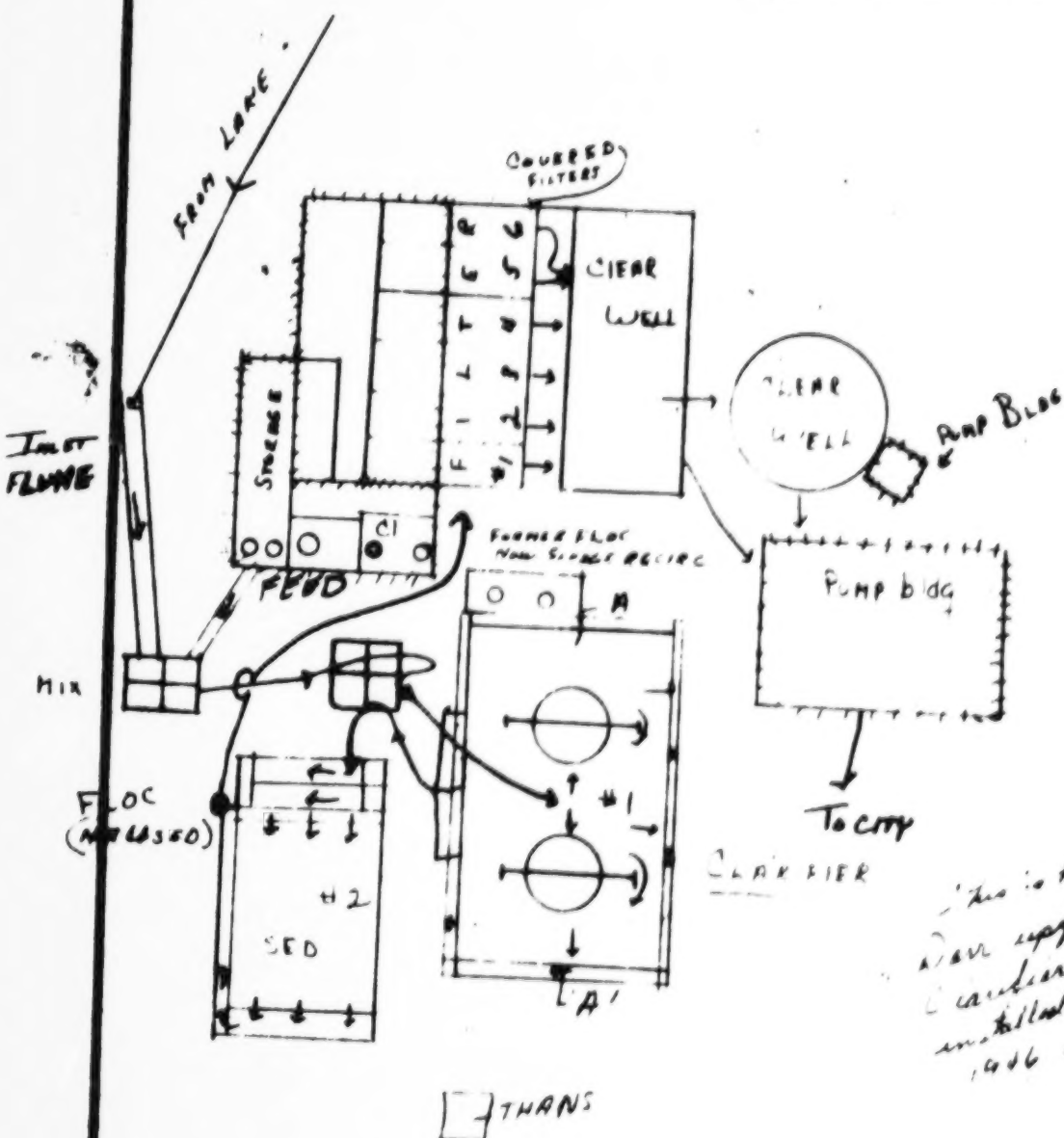

#19
11' DEEP
BAFFLE
UNDER
SED
OPEN
33'6"
44'6"
UNDER
FLOC
COVERED
OUT HERE
ALUM
FEED
FILT
CL2
EMERGENCY
GEN
125
200
300
75
60 M
PRIMARY
ROOM
SLOPE


Lab
High Pump
Floc #2
Floc #1
Sed #1
Sed #2
FM #4
FM #3
FM #2
FM #1
WW
1100 ft.
00000
100 ft. tunnel
through pump pit

#21

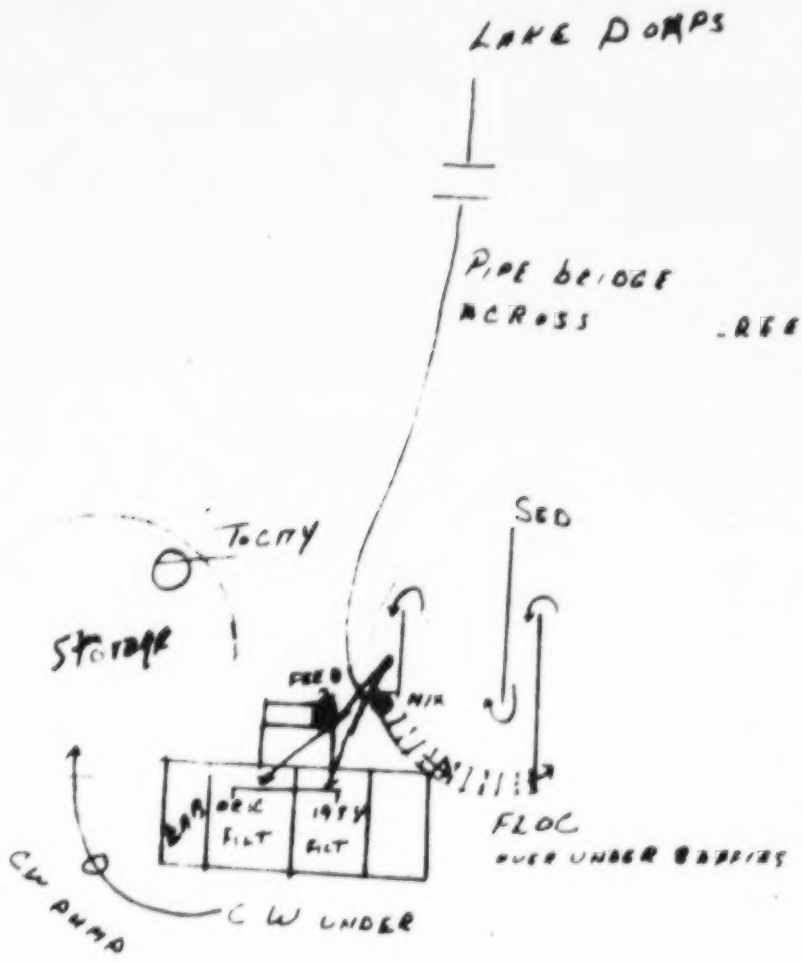


CLAR SECTION A-A'

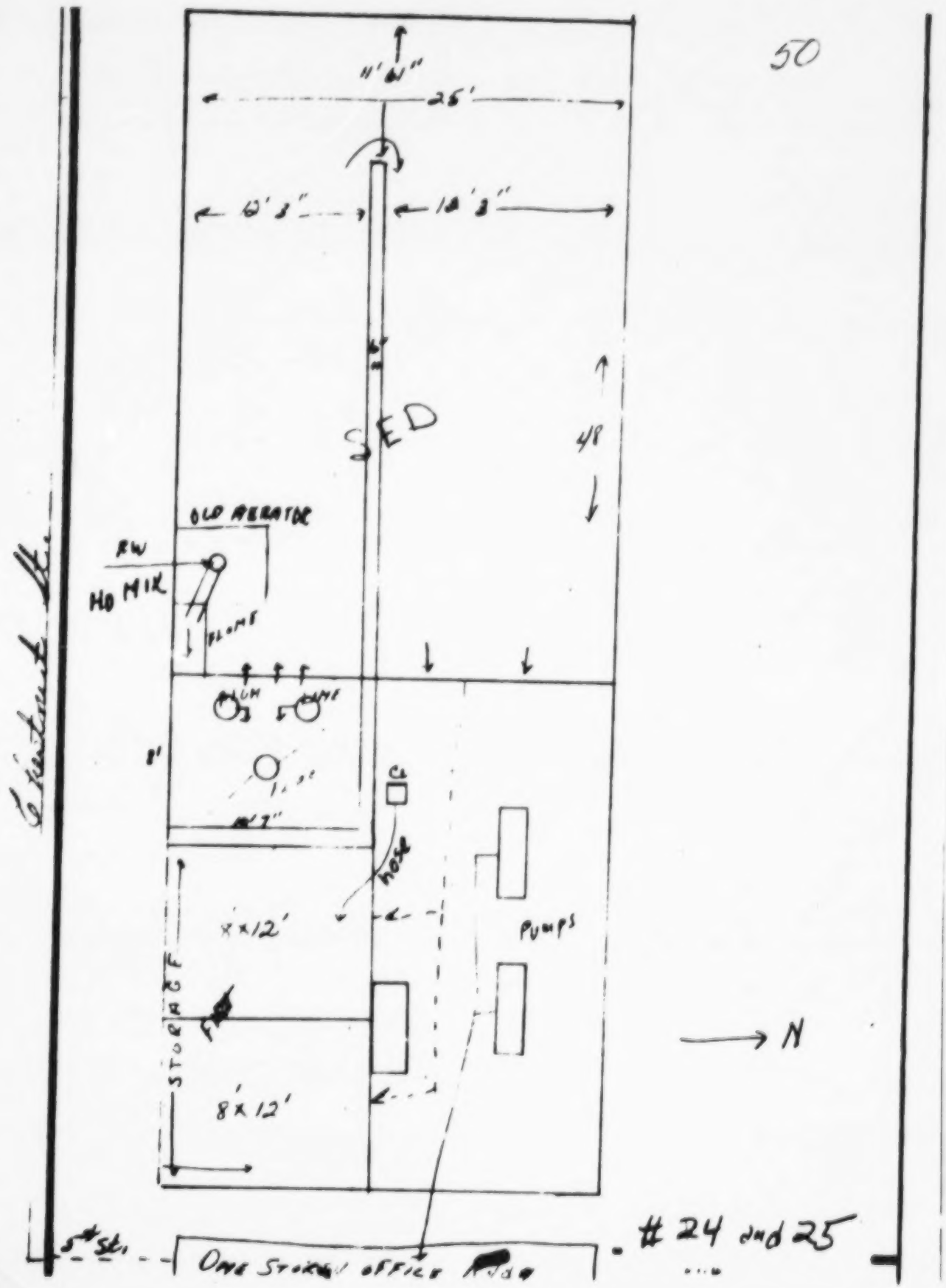


This is A view upflow clarifier installed in 1946 S.E.D.

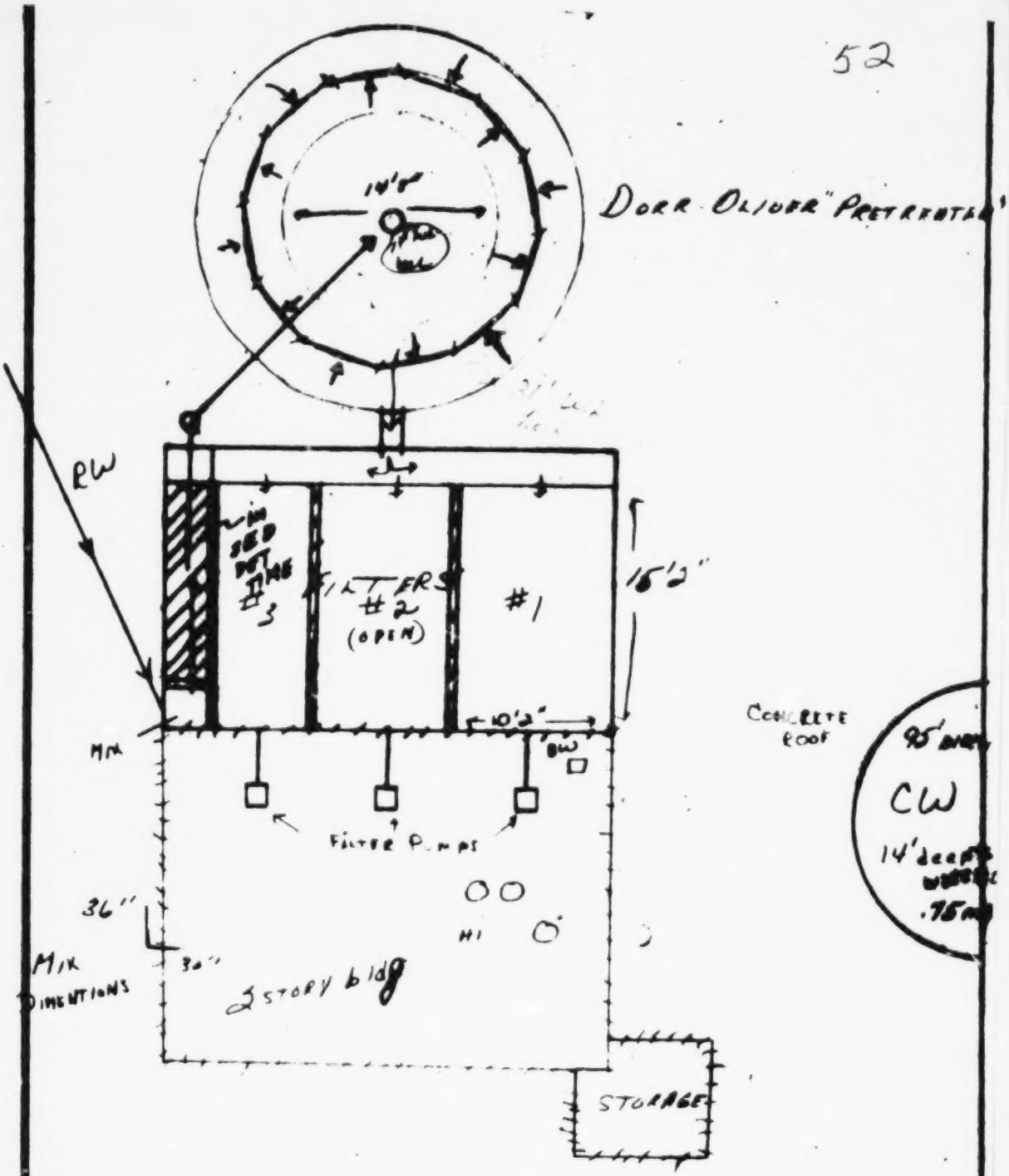
#22


LAKE PUMPS
PIPE BRIDGE ACROSS CREEK
TO CITY
STORAGE
SED
FLOC
CW PUMP
C W UNDER

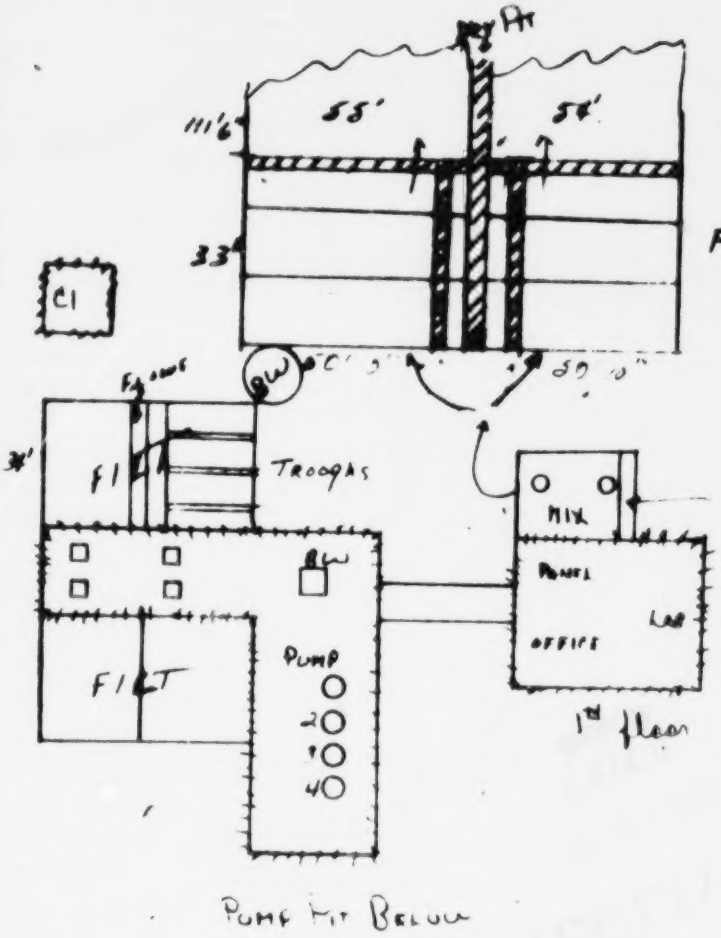
#23

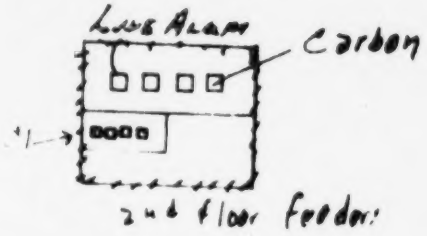

11'6"
25'
10'3"
48
OLD AERATOR
RW
HD MIX
FLOAT
8'
1.5"
2"
HOSE
8'x12'
PUMPS
STORAGE
8'x12'
N
5th St.
ONE STORY OFFICE
#24 and 25

FLOC
RW
PUMP IN BASEMENT
MIX
350'
5'D
To FL TOWN & STANDPIPE
FLAGSTONE BOTTOM


14'0"
DORR OLIVER "PRETREATED"
RW
IN SED PIT #3
FILTERS
#2 (OPEN)
#1
15'2"
10'2"
CONCRETE ROOF
95'
CW
14' deep
.75
MM
BW
FILTER PUMPS
36"
30"
MIX
DIMENTIONS
2 STORY bldg
STORAGE

#28


111'6"
55'
55'
SED
33'
FLOC
CW
1964
CW
1958
Troughs
MIX
PUMP
OFFICE
1st floor
PUMP PIT BELOW


LIME ALARM
Carbon
2nd floor Feeders

..... : housed

#29